2 Music and morphing

This chapter examines background musical contexts and their relationship to morphing. It involves musicological description and analysis of a range of contextually relevant music and morph-like composition practices. It is accompanied by audible musical examples and transcriptions. The focus here is on music that is directed, produced or composed manually - automated composition techniques are reserved for the following chapter.

The first section (2.1) explains Mainstream Electronic Music (MEM), the musical genre within which the research is situated. This is fundamental for comprehending the musical intentions, relating to the musical outcomes of the research and understanding various decisions that informed the software outcomes. Occurrence of morphing and morph-like practices within MEM is also examined.

Investigating music *outside* of MEM (2.2) was also important, but not so much for contextualising the research as for providing developmental inspiration – ideas from other genres that might be combined, modified or recontextualised into MEM compositional morphing algorithms. As well as this, the study of morphing in a broader context established a baseline against which the novelty and significance of new techniques and approaches could be judged.

Overall, the most diverse examples of morphing were found in the avant-garde, where musical boundaries are pushed aside. In contrast, morphing in other genres, both inside and outside of MEM, was less varied, due to stylistic and technological norms. Technology was found to be a major limiting factor, particularly in interactive situations and electronic music contexts, due to the onus on computation and the requirement that the processes are responsive in realtime; an observation that further highlights the demand for this research. That said, the situation is complex, as style and technology both motivate and influence the development of the other. What is seen by one person as a technological limitation might be seen by another as a cherished “feature” of the genre.

2.1 MEM: context of choice

MEM was the musical context of the research. The music generated by the morphing algorithms fell within this category, as did the source and target music that was fed into them. Occasionally, for the sake of experimentation, other styles were applied, but all of the algorithm designs were tailored to MEM. Because of the centrality of this genre to the research, it is important to clarify exactly what is meant by MEM and summarise key musicological features, as is done in 2.1.1 below. With the knowledge of this musical context, the various decisions regarding system and algorithm design, as explained in later chapters, can be shown to be consistent with the music and therefore justified.

Briefly, MEM includes any form of metric electronic music based on loops and layers of different synthesised or sampled instruments and sounds. Styles include electronica, downbeat, instrumental hip-hop, break-beat, and many other genres. Electronic Dance Music (EDM) genres that feature strongly in the research include drum and bass, house and trance. Despite the 'underground' origins and status of much EDM and other genres, it is clearly more mainstream than the classic forms of 'electronic music' such as those of the electro-acoustic and acousmatic traditions, which, with the typical absence of pulse, loops and instrumental layers, are not included within the scope of this thesis but are mentioned in passing in the following section (2.2) that deals with genres outside of MEM.

The term 'mainstream' was chosen over 'popular', due to possible confusion with the much-discussed corpus of 'pop music'. While pop music is not necessarily excluded from MEM, a number of the styles mentioned would clearly be outside of pop music. Musically, the focus of pop music is more on vocals and lyrics, while MEM is defined here as being more concerned with rhythm and instrumental elements. Following the tradition of EDM (Shapiro 2000: p 77-78), a piece of music will be referred to as a 'track' rather than a 'song' due, by and large, to the lack of traditional, lyrical style 'singing'.

There exist a plethora of styles and, as MEM is relatively new and constantly evolving, the terminology of sub-genres is problematic. In practice, tracks usually possess features of multiple genres and so categories are often used as adjectives to describe a particular piece of music, for example: 'dark-trancey-two-step-raga-hardcore'. Rather than attempting to work with these loosely defined terms, or attempt to define them, a brief musicology of MEM has been carried out, to define the general features in musical terms that can usefully inform the development of musical algorithms and representations.

Following the musicological discussion, a review of morphing in MEM is presented, with examples of both transitioning and hybridity. As multiple-source hybridity (**syncretism**) is intrinsic to many compositional practices, an exhaustive review would be intractable; therefore only a few key examples that are indicative of more widespread occurrences are shown. Transitioning from one known state to another is less common than hybridisation, but nonetheless widespread, as there are many situations that require such shifts and as with hybridisation, only a few key examples will be used. Morphing appears less common still: however, a complete search is impossible.

This review is important because it provides some idea of the existing, informal morphing techniques, which allows those formalised ones that I developed to be positioned and assessed musically within a larger field. As well as this, the act of surveying provided general inspiration for algorithmic developments. Overall, this serviced the twin goals of the research: to formalise existing approaches and explore new ones. It was found that, despite their abundance, few MEM morphing techniques have been formalised to the point where algorithms could be developed and for realtime situations, the range of aesthetic possibilities are much smaller due to this. Those few formalised morphing techniques that exist are dealt with towards the end of the next chapter (3.4).

2.1.1 Musicology of MEM

Having introduced MEM as the context within which the musical outcomes of the research are located, a more detailed examination of the general musical traits of MEM will now be given. The analysis of MEM in musical terms is pivotal to an understanding of the research as a whole, as every developmental decision was informed by my intuitive understanding of the genre. My knowledge of MEM is made explicit during this section so as to familiarise the reader and also to define the genre more clearly.

Although sound manipulation and vocals are prevalent within MEM, the discussion below pertains mostly to instrumental and note based aspects of the music. This is because the research is on algorithmic music rather than sound synthesis. Due to timbre being pervasive within MEM but only of secondary relevance to the study, it is discussed briefly where relevant, rather than separately and in depth.

An overarching influence on the composition techniques of MEM is technology, which means that an appreciation of the music is assisted through knowledge of the tools that are used. Throughout the following discussion, fundamental aspects of music technology are raised and it is assumed that the reader is already familiar with these. For clarification, the glossary can be

consulted. Despite the role of technology, music remains the primary focus of this section and the discussion shifts through key topics that define MEM: Loops and layers, rhythm, tonality and structure.

MEM: Loops and layers

MEM is constructed from repeated loops (ostinatos) of different layers (instruments), with cues to mark the addition or removal of the layers and other changes. This can be represented conveniently through the layout of any sequencing or sound-editing tool.

Figure 1 Five different layers of loops in the *Fruity Loops* sequencer

All sequencer tools have multiple horizontal layers, each showing a visualisation of the music that plays on that layer, be it a block representing a loop, a pattern of notes or an audio signal. There is usually the ability to loop or copy aliases of the musical patterns, thus affording the use of repetition, which is widespread in MEM. Usually, the loop lengths are powers of two above two, although other lengths based on ratios of three and (much more rarely) other numbers are used. Technically, a producer may implement any number of different layers for ease of manipulation; however, often there are only a few that are easily distinguished by the listener, who is oblivious to the visual layout preferred by the tracks' creator.

Typically, each layer will perform a different role in the music and be allocated a different instrument. This is in a similar way to much 'homophonic' music, which can be defined by the two roles of melody and accompaniment. Common roles for MEM are: percussion, bass, accompaniment, lead, sound effects and cues. Each of these functions can encourage a vast range of effects (Pratt 1998) in the listener, including: energy/intensity (Wundt 1896); predictability or chaos (Meyer 1956; Huron 2006); mood (Huron 2006) and atmosphere (Butler 2006). However, particular roles afford different effects, often indirectly or through combination with other roles.

Percussion

Percussive, or 'rhythmic' (Butler 2006: p 180), layers are comprised of short events with fast attacks that vary chiefly in dynamic and, to a lesser extent, duration – rather than pitch, timbre and other dimensions. Because of this, the percussion is apt to express the overall level of energy in the track and, through highlighting the rate/tempo and metre, can set up expectations that other roles work around. In doing this, the percussion can also partially indicate the function of the music, that is, whether it is to be danced to (~2.1) or listened to (~2.2). Having said this, the music of styles such as 'Intelligent Dance Music' (IDM) , 'braindance' or 'intelligent techno' can blur such boundaries, and people will listen or dance to whatever they please.

The length of the percussion loops are typically quite small, for example, two beats (~2.3, listening to percussion only), four (~2.4) or, less commonly and usually less obviously, eight (~2.5) or more. If they are long, this is usually counterbalanced by a substantial amount of repetition, or looping of fundamental percussive elements. For example, the kick and high hats might follow a repetitive pattern within the scope of one beat, but the snare and clap might vary towards the end of an eight or sixteen beat cycle (~2.6). This kind of variation fulfils the role of a hypermetric **cue** (discussed below).

The percussive layer can itself be perceived as containing a number of sub-layers, or segregated streams. Typically, there is a sub-pulse metered out in the high frequency spectrum, for example high-hats, shakers, bells, ride cymbals and/or equivalent; a backbeat pulse kept through the mid to high frequency sounds such as the snare, clap, conga, cowbell and/or equivalent; and a downbeat and onbeat pulse in the low frequency, for example kick, toms, a descending sine wave chirp and/or equivalent. This multi streamed view is enhanced by polyrhythmic and otherwise contrasting patterns and diminished by unified patterns and audio compression. Cymbals and fill patterns are usually on a separate, much longer loop and, despite often being from the same drum kit, perform a different function – that of the **cue**, which is dealt with further below.

Percussion is typically expressed using various short sounds with fast attack, often sampled from drum kits and manipulated, or synthesised through an array of techniques, classically subtractive synthesis for high-hat, snare and clap and descending sine wave for kick and toms. Non-standard sounds which do not replicate the drum kit, but nonetheless bear some resemblance to the musical functions of the various items in the kit, are used in more abstract or experimental styles, for example minimal techno (~2.7) and alternative electronica (~2.8).

Bass

The **bass**, as a lower register, monophonic tonal part, is particularly suited to provide the root pitches of the chord sequence (~2.9) or drone (~2.10), but also often works with the beat to help define the metre (~2.11) or fatten up the kick drum (~2.12, ~2.13); or against the beat to generate more complex patterns (~2.14).

The length of the bass loop is generally longer than the drum loop, particularly when the bass defines a chord progression (as opposed to a drone). Often, particularly in styles where the metre is reinforced by the bass, the rhythmic pattern is repeated after as little as one beat, typically on the offbeat so as to hocket with the kick drum (~2.15), while the pitch pattern can change to define the root of the chord, usually over four (~2.9), but often also eight (~2.16) or, less commonly, sixteen or more bars. As with all parts there will often be variations to the pattern towards the end of a long cycle, which is effectively a **cue**.

When the bass acts as a drone, the pitch and rhythmic pattern are both repeated. In strict definition, a drone occupies only a single pitch, but often a kind of drone can be set by short looped oscillation between two pitches, usually with the implication of one being dominant (~2.18). Often, bass loops are small and do not indicate a chord progression so much as a drone-riff. This is clear in (~2.19), where the bass riff is repeated throughout the entire track.

Bass tones can be sampled from instruments or synthesised, classically using combinations of saw, square and sine waves in subtractive synthesis. The synthesis techniques used in other tonal parts, such as the **lead** and **accompaniment**, are similar to those used for the bass, but in different registers.

Accompaniment

The **accompaniment** generally aims to complement the other parts through background harmony. This provides the listener with chord-type and, over time, key/scale information which can symbolise different moods. It typically takes the form of a polyphonic tonal instrument, mid-range, playing chords (~2.20). This includes “synth pads”, which are sustained harmonic and textural sounds (~2.21), and chord stabs (~2.24). Pads often feature in arrhythmic and textural sections, such as breakdowns and intros (~2.23). Chord stabs, with the fast attack and decay, have rhythmic significance and therefore can be used to reinforce or contrast the metre, or, if applied sparsely, can serve as punctuation cues for the structure. The loop length of the accompaniment is often is the same as the bass, as they both define the tonality and chord progression. Despite this, they can often differ in length, for example when the bass is a short-looped drone, the accompaniment might still vary over a longer period (~2.25).

Lead

The **lead** is typically tonal, melodic and monophonic, in a mid to high pitch range. It is mostly used to express musical gestures, melodies, tunes or riffs through sequences of notes. It can work with or against the metre (with, ~2.26, ~2.29; against, ~2.30 [ritardando], ~2.28 [a layer of the lead is 3 against metre 2]), harmony (with, ~2.26; against, ~2.27) and patterns in other parts. Due to the range of musical possibilities that the lead may cover, it is well suited to manipulating the listener's sense of musical expectation, which is fundamental to musical enjoyment (Meyer 1956; Huron 2006).

As a 'free-ranging' part, the **lead** loop is typically no shorter, and often longer, than the length of the bass and accompaniment (~2.31), although sometimes involves heavy repetition. It is the electronic equivalent of the lead vocal or guitar that is prevalent in acoustic genres. This is not to say that lead vocals or guitar do not occur frequently in MEM, but when they do, they will fulfil the same role of the synthesised lead (hence it is unnecessary to include a description of **vocals** as a role in itself).

The various timbres used for lead are not mutually exclusive and, as mentioned earlier, there may be more than one lead, each with more or less lead-like qualities.

Sound effects

Sounds effects are usually arrhythmic, textural and often created from samples of found sounds (~2.143), voice (~2.33), and any combination of Digital Signal Processing (DSP) and synthesis techniques (~2.32). It is equivalent to what Butler (2006: p 180) calls 'atmospheric'. They often add extra-musical meaning and/or character to the track through literal (~2.34) or abstract (~2.36) means.

Sound effects on a short loop tend, over time, to integrate musically into the metre and pitch space of the track (~2.41). Sound effects on a medium length loop, around eight to sixteen beats, may take on some qualities of the accompaniment or lead, while sound effects on a longer loop tend to perform the function of cues, which are explained directly below.

Cues

Cues mark significant points within the music, often allude to some form of change and always occur with a length of loop that is longer than most of the other roles. They usually occur at the end and the beginning (~2.37) of a section, often marking an increase or decrease in intensity through the addition (~2.39) or removal (~2.38) of a layer. Like any other role, cues can play with

the listener's expectations. For example, within drum and bass, the backbeat snare is often used as a cue to foreshadow an upcoming section (~2.83). Sometimes they foreshadow a change that does not occur, defying the expectation. In this case, the cue nonetheless adds significance to the point in the cycle at which it strikes and punctuates the passage of time. Sometimes it is difficult to distinguish between a cue and a new layer (~2.86). Cues can take the form of any sound, for example, cymbals, reverse cymbals, reverse drums and sound effects. In most parts, drums, bass, lead and accompaniment, some form of variation will occur towards the end of the cue-loop and this itself acts as a cue.

Ambiguous roles

The roles of bass, accompaniment, lead, sound effects, cues and rhythm are sometimes difficult to distinguish, especially when they are purposefully blurred and inconsistent, being swapped back and forth between instruments. For example, note how this lead synthesiser (~2.42.1) becomes delayed and reduced to the background so as to temporarily become tonal accompaniment, first in a subtle way (~2.42.2) and then stronger (~2.42.3). Another example is the "blip" in (~2.43) which could be interpreted as fulfilling the roles of both lead and percussion. Lead arpeggios, while technically containing no chords, often fulfil the role of background harmonic accompaniment. This is clear in the following example when the chords end and the lead arpeggio takes over (~2.44.1). Later, an additional lead is added over the arpeggio (~2.44.2). The bass can temporarily become a lead if it is shifted up to higher registers (~2.45) or brightened with a "squelchy" filter and varied melodically (~2.145). The snare drum can be pitch-shifted in a melodic way (~2.144). As well as this, not all of the roles will be present all of the time and often there will be multiples, for example rhythm and auxiliary rhythm, lead and second lead, multiple bass lines. Many examples abound that highlight the difficulty in generally defining the aforementioned roles; after all, music that is difficult to define is an inevitable result of the drive towards uniqueness and innovation. However, such examples usually do not deviate drastically – tracks with many attributes that differ markedly from the norm are classed as "experimental" rather than "mainstream".

Rhythm in MEM

As outlined above, MEM is a style built from looped layers of differing roles. In most cases, the repetitive timing and tempo of the loops in MEM is almost flawlessly consistent, although the material itself is not necessarily precise and mechanistically quantised. The overarching regularity reinforces underlying rhythmic constructs such as beat, metre, hypermeter and accents of special meaning including the downbeat, backbeat and others. It is often observed that rhythm in MEM is of greater significance than in many other styles of music (Shapiro 2000;

Neill 2002; Butler 2006: p 4-5), however it is nonetheless possible for the nature and ambiguity of such idealised rhythmic constructs to change radically from piece to piece, over the course of a single track and from listener to listener; an observation that is supported by Huron's discussion of mental representations of expectation (Huron 2006: p 231).

Within a particular layer of a particular passage, the patterns of event inter-onset, event duration, articulation and other, non-temporal, qualities, can suggest phrase or grouping boundaries of various strengths at particular points in time (Lerdahl and Jackendoff 1983; Krumhansl 2000; London 2007). The density of events correlates to levels of intensity (~2.46) or pace (~2.47). Both surface level rhythmic patterns and the metres that appear to be abstracted from them are conceived on a continuum from even through to irregular. Following Butler (2006) and the colloquial language of MEM, I represent the continuum of regularity through the two contrasting styles of "four on the floor" (~2.48) and "breakbeat" (~2.146).

That metre is built from observations of rhythmic events is strongly supported by a range of psychological studies, summarised by Krumhansl (2000: p 163) and Huron (2006) and continuums of rhythmic irregularity have been explored in psychological investigations (Krumhansl 2000: p 164). While even rhythms are fairly narrow in definition, irregular rhythms have been described and conceived in multiple ways, without any apparent unified approach (Thaut 2005: p 11-13; Butler 2006: p 81; London 2007). While the listener generally has the ability to attend specific streams or compound them, particular cues and patterns within and across layers can direct attention, thus further influencing the perception of rhythm.

Beat

The **beat** or "tactus" is fundamental to rhythmic perception in MEM and is defined here as an imaginary periodic event, the frequency of which resonates with the frequency of audible events in the music, at a rate that is comfortable to tap or "beat" along to. This view is supported by some music psychologists (Krumhansl 2000: p 160; Huron 2006: p 176), however, variations have been proposed by others, for example, Thaut notes that some authors perceive the beat as the "audible (rather than imaginary) pulse markings" (Thaut 2005: p 8). Butler goes further in stating that beats, in an EDM context, are "heard, felt and enacted" (Butler 2006: p 91). While this is clearly a popular understanding of the term, it is taken here to be a colloquial definition, secondary to the formal idea of an imaginary beat as defined above, due to it being less broadly applicable to MEM and styles that aren't "four-on-the-floor" or dance-oriented. Like the beat, "pulse" is taken to be an abstract periodic event, the frequency of which is related to the frequency of perceived events, but is generalised so as to be applicable at any cognisable rate, not only the rate which is most easily tappable (Parncutt 1994).

The beat can be divided into various sub-pulses, typically at rates that are a half, quarter or a third of the beat, however there are no doubt many deviations from this general trend, for example, when they are overlaid together (~2.61). Complicating the perception of sub divisions are the various forms of quantisation – groove-templates and swing/shuffle. While standard quantisation will align all events to the closest beat or subdivision specified by the producer, swing will shift every second note later in time (after/behind the beat) a certain degree ranging from on the beat/pulse to almost on the next (hard swing, ~2.51). Often, the amount of swing is set to imply a triplet subdivision (~2.50). Groove templates have an "offset" value for each quantisation point, enabling the grid to be distorted in any way, but often inducing values from human performances, as is the case with *DNA Groove templates* (Chokalis 1999) and Desain and Honing's induction of expressive timing variation (1989; 1992). Obviously swing is encompassed by the groove template style representation. The technique is typically applied over multiple beats, encompassing one or more bars and is thus also relevant to the concept of metre.

Metre

The contemporary concept of metre is an imagined pattern of emphasis within the bar, a hierarchy of different accent strengths at various points in the bar. Computational models of metre that automatically derive the emphasis at each position of the bar from adding all of the note occurrences and their strengths (Desain and Honing 1992; Huron 2006) have tended to match analytical expectations (Lerdahl and Jackendoff 1983), giving credibility to this notion of metre induction. However, in practice, metre is obtained not only from the surface, but also from schemas – as musicians will know, the underlying metre known by the performer can easily be hidden from the audience. Butler (2006) examined a kind of metrical obfuscation that is common to EDM, "turning the beat around", whereby the first layers that are introduced imply a metre that becomes untenable when the primary rhythmic layers enter (~2.52). Temperley (2001: p 217) and Huron (Huron 2006: p 279-281) describe a similar technique in classical music which they call "the garden path" phenomenon. Clearly, the metre inferred by a listener is dynamically revaluated as the music progresses as well as being informed by previously recognised templates (Desain and Honing 1992; Hannon, Snyder et al. 2004: p 957). If we take metre to be a kind of idealised periodic expectation of rhythmic emphasis, the following observations of expectation are illuminating (Huron 2006: p 231):

> *"**Schematic expectations** represent broadly enculturated patterns of events. Different schemas may exist for different styles or genres, as well as for common patterns that cross stylistic boundaries …*

> ***Dynamic expectations*** *represent short term patterns that are updated in real time especially during exposure to a novel auditory experience such as hearing a musical work for the first time."*

From this, a continuum ranging from schematic to dynamic metres can be conceived. Underlying these expectations is a seemingly inbuilt ability to conceive simple rhythmic patterns based on ratios of 1:1 and 1:2 – that is, the ability to replicate rhythms based on other ratios such as 1:3 and 1:4 appears to be learnt (Krumhansl 2000: p 162).

Traditional music theory has a set of metric schemas, such as 2/4, 3/4, 4/4, 6/8 and so on that apply fairly well to a corpus of pre 20th century classical music. Theory surrounding MEM has not reached the stage where an appropriate set of metric templates can be formalised and widely agreed upon and it is obvious that the traditional models are somewhat inadequate, when arguably the entire genre of EDM, in all its rhythmic complexity, is most accurately described simply as 4/4 (Butler 2006: p 76). In MEM more generally, odd time signatures confusing syncopation (~2.54), skipped beats (~2.53) and macroperiodic polyrhythms (~2.55; ~2.56) do occur, but clearly remain in the minority. Although the metric schemas of MEM are far from canonisation, it is clear that particular patterns are widely used within particular styles of MEM and thus likely to be compressed into a metre by listeners that are highly exposed to the music.

Metre in Four on the Floor

Perhaps the most common metre is indeed 4/4, which is typical of 'Four on the Floor' (FF) style dance rhythms. Musicians commonly refer to different pulse cycles within the 4/4 metre (Wikipedia 2006; Kernfield 2007; London 2007): downbeat, backbeat, onbeat, offbeat and upbeat. The downbeat is the first beat in the bar. The backbeat is the pulse on beats two and four. An onbeat is literally any event on the pulse of the beat (four beats per bar). The offbeat is any subdivided pulse that is not on the onbeat, including the eighth or sixteenth note pulses in-between the beats. The upbeat is any event leading directly into the next downbeat (see diagram).

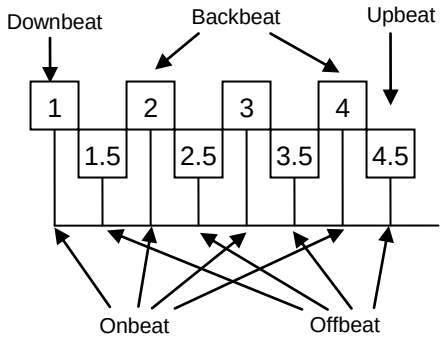

Figure 2 **Diagram showing the positions of the downbeat, backbeat, upbeat, onbeat and offbeat in the 4/4 bar.**

Some variations to the typical pattern of downbeat-offbeat-backbeat-offbeat are notable because they are widespread and thus stylistically recognisable. Ragga, Soca and many other electronic music styles found from the African Diaspora will have a FF kick drum but emphasise the offbeats and subdivisions much more than the standard 4/4, often through the snare (~2.57, ~2.58).

Intense styles of dance will have a 'galloping' offbeat pattern (~2.62) which highlights a 16th note pulse. In psi-trance and gabber, the beat is often subdivided into triplets while maintaining four per bar. The extent to which these patterns are perceived as schematic or dynamic ultimately depends upon the listener's familiarity with the music. It should be emphasised that these are general observations of trends rather than rules and that many tracks are designed to break the standard patterns of their sub-genre in some way.

Metre in Breakbeat

Breakbeat (BB) patterns would be formally classified as 4/4 but cover a plethora of distinctive grooves that contrast with the typical 4/4 pattern more markedly than FF styles. The biggest difference is the change in role of the kick and snare. In FF, the kick keeps the onbeat pulse and the snare keeps the backbeat pulse and the two collide regularly on each backbeat. With BB patterns, the kick and snare rarely occur simultaneously and in many cases could be heard as two different sounds on the one stream. The perception of the high-hats, kick and snare as being a single voice is further enhanced by audio compression of drum loops, so that at any point in time only one of these layers is pushed to the foreground. In some styles of BB the rhythmic patterns can change so frequently that this voice takes on lead-like qualities, playing against the underlying metre to create metrical dissonance. Despite this, there are many repetitive styles of BB, as well as particularly widespread samples such as "funky drummer" (~2.60) and "amen break" (~2.59) that, I suggest, have contributed to some kind of ambiguous metric template of

BB. However, I do not consider these to be **veridical** (Huron 2006: p 275), as most BB listeners have not heard the original tunes from which they are derived. I distinguish between five interpretations of BB – polyrhythms, additive rhythms, syncopation, beat-roles and transformations, each of which are implied to greater or lesser degrees by particular patterns.

Polyrhythms

The definition of polyrhythms used here follows Arom (1991), as the "ordered and coherent superposition of different rhythmic events". This is favoured over the term cross-rhythm which appears to be controversial (Chapman 2006; London 2007) and hemiola appears to be specifically related to the case of three over two or four polyrhythms in 3/4 or 6/8 time signatures (London 2007), and thus does not apply to BB which is in a 4/4 signature. Importantly, polyrhythms may be truncated, mid-macroperiod (Arom 1991: p 231), to fit with underlying metric and hypermetric cycles and still be considered polyrhythmic[1]. For BB rhythms, polyrhythms usually only apply to four or two over three type patterns – for example, the two over three kick drum in the following phrase (~2.63):

```
1---2---3---4---
k   k   k k   k   k
```

Similarly, the eight beat snare pattern in (~2.67) contains two, two over three type patterns:

```
1---2---3---4---5---6---7---8---
    s   s  s   s   s  s   s   s  s   s
```

Soca and raga rhythms, although closer to FF than BB, also often exhibit a polyrhythm four (snare) over thee (kick) (~2.68).

Such polyrhythms often have the property of maximal evenness and individuation and may thus also be considered "diatonic" (Butler 2006: p 84-85), however this property appears to be more of an interesting side-effect than a rule that can be schematically applied to MEM.

Additive rhythms

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[1] Although not limited to BB, it is worth noting that extended, full macroperiod polyrhythms are often introduced into the music through delay effects set to two thirds and other divisions of the beat or bar. This is a technique endemic to dub and other reggae influenced electronic music genres (~2.69), but used throughout MEM.

An additive rhythm is viewed as a string of atomic rhythmic elements, each consisting of a certain number of beats. The notion of rhythm as being either additive or divisive was originally coined by Curt Sachs (Sachs 1953) who related divisive rhythms to bodily feelings of movement and additive rhythms to speech, a notion that fits well with the idea of the BB drums taking on lead-like qualities. That is, if the kick and snare are able to be seen as two different kinds of accents of speech-like voice, additive rhythms can often seem like a more appropriate interpretation. For example, the beat from the BB classic *Unfinished Sympathy* by Massive Attack (~2.70) can be interpreted as 2+3+1+2. This is obtained by compounding the primary kick and snare attacks into the one rhythm, using the eighth-note sub-pulse implied by the primary high-hats as a counter. Some analysts might collapse the 1+2 at the end into a 3 on order to fit theoretical notions of diatonic rhythms, however, considering the strong emphasis of both the kick and snare I feel that 1+2 is more appropriate. As 2+3+1+2 the pattern reflects the widespread tendency to increase the density or rate of events towards the end of a cycle, which is, in this case, a single bar.

Syncopation

Syncopation has slightly different definitions throughout the literature, however it is taken here to be accentuation of weak points in the metre, following Butler (2006: p 85). With this definition, the notion of a syncopated metre may seem somewhat nonsensical – how can a metre, as a pattern of emphasis, be defined by accentuation of weak points? However, if we consider that a *rhythmic pattern* can be syncopated, and that after repeated exposure to the minds of listeners, this pattern becomes a style eventually attaining the status of *schema*, it would be plausible to say that a new metre has been spawned that is syncopated in comparison to the original metre. Classic examples are the funky drummer pattern (~2.60) and the amen break (~2.59), which have become almost ubiquitous to BB styles. Butler makes the case for the syncopation interpretation of BB by noting how the:

> "*second and third (snare) hit seems to dance about beat three without actually landing on it … Through these behaviours, however, both attacks call attention to where they should be, in so doing invoking the presence of the unarticulated beat*" (Butler 2006).

I call this a "Chick-A-Chick" (CAC) (Wooller 2003).

The CAC over the third beat is a widespread characteristic of BB and is perhaps becoming part of an underlying schema for BB metre. This speculation is fuelled by the new forms of stronger CAC emphasis that have begun to emerge over the years. From early drum and bass, an example of the CAC being heavily accented by bass squelch parts is evident (~2.64). Stakka and Skynet occasionally reinforce the CAC with a kick instead of a snare (~2.65), without losing

the BB feel. This was done to even more popular acclaim by Groove Armada recently in 2006 (~2.66).

Beat roles

I have previously proposed the notion of "beat-roles" (Wooller 2003) and formalised this into a "generative grammar of breakbeat", initially with the idea of being able to create all the possible patterns of BB kick and snare, and only these, from a small set of rules . These rules constitute a formalised schema for BB and thus must be considered when discussing notions of BB metre. Accepting the limitations of sixteenth-note pulses, the results are quite variable, being able to produce a huge range of different patterns. At the same time, the patterns sound very much like BB and have been applied successfully to a number of live performances. It is important to note that this particular piece of software (*LEMu*) has already been assessed for my Masters and is therefore not part of this research. However, it is still relevant to mention the concept of BB "beat-roles".

Any event occurring in the first two beats of the bar is considered "primary" (**p**) and any event in the second two beats is considered "secondary" (**s**). An event can either be **p** or **s**, "complement" (**c**) the **p** or **s**, or "lead" (**l**) into the subsequent beat. Each role of **p, pc, pl, s, sc** and **sl** has a chance of appearing and a chance of occurring on two or three different sixteenth note slots, depending on the role and the rhythmic layer (kick or snare).

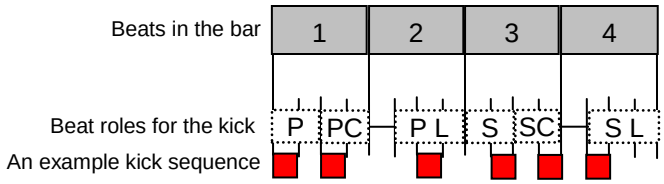

Figure 3 **The portions of the bar that can fulfill the various beat roles for the kick drum: primary (P), primary-complementary (PC), primary-leading (PL), secondary (S), secondary-complementary (SC) and secondary-leading (SL). An example of one possible configuration is shown by the red squares.**

The precise probabilities for this grammar were determined through music analysis and transcription of a variety of club drum and bass. Another approach could be to train the system on real examples. The simple rules defined by this grammar can represent and generate many fundamental BB patterns. Interestingly, a key feature of BB appears to be the downbeat and the first backbeat. As long as these two features are preserved, a huge variety of other rhythms, particularly with the kick and snare appear possible, while remaining within the BB style. For styles as rhythmically diverse as BB but nonetheless recognisable, templates such as these may

be suitable for representing the metre, as periodic rhythmic expectations. An example of the output of the "beat roles" generative grammar for BB is available (~2.71).

Transformations

Finally, it seems obvious that much of the new patterns that have emerged are the result of certain transformations, afforded by sonic and symbolic (MIDI) editing techniques available on the computer. These include phase-shifts, repetitions, rate changes, reversals and others. Many of the patterns in BB are obviously the result of such processes (~2.72; ~2.78), and so it is worth considering the implications of these to BB metre. As for formal schemas, Nick Collins has created software that automatically splices BB samples in the style of studio drum and bass (Collins 2001), while my own *LEMu* software includes functionality to transform rate, phase and to repeat particular sections. Despite this, I suggest that transformations have actually had a small impact on the metre itself. Particular transformations may have been used so often as to become well-recognised, but still not a predictable part of the one or two bar periodic cycle that would constitute the metre of that sub-genre. However, when it comes to the *hypermeter* of BB, and also more generally of MEM, such transformations are endemic and come in the form of drum **fills** at the end of long cycles.

Hypermeter

Hypermeter is the pattern of emphasis over periods beyond the metric cycle (Lerdahl and Jackendoff 1983; Huron 2006) and has been touched on by the previous discussion on cue layers. Within MEM, the form of hypermetrical structure is fairly consistent across most sub-genres – the period leading up to the end of a cycle deviates in some way from the patterns that are repeated throughout most of the cycle. I refer to this period of deviation generally as a cue, however, the term **fill** is often used to refer to a rhythmic cue, which is the most common form of cue in MEM. The fill is usually comprised of either a removal (~2.81); addition (rhythmic layer ~2.82); sonic transformation, including reversal (~2.74); rhythmic transformation (~2.79) including phase and rate changes (~2.84); rhythmic variation (~2.73), repetition (~2.75), substitution (~2.85) or any combination of these. Rhythmically oriented fills create metrical tension which is generally resolved in some way as they lead into the next cycle. Sonic and tonal fills serve to pique curiosity or foreshadow a particular mood.

After the fill is the standard point at which structural changes in the music, such as breakdown, occur. While this pattern is a general trend, there are a number of exceptions. For example, occasionally the fill is on the first bar of the next cycle (~2.87) or start point of cycles in different parts are offset so that a fill in one layer will occur halfway through the cycle of another layer.

Hypermeter is also relevant to musical form, however further discussion of this topic is reserved for the section on “Structure” below.

Tonality of MEM

Tonality is defined here as the way a sense of tonic pitch is or is not suggested in the music and the way other pitches, if present, are organised with respect to it and each other to achieve particular musical effects. This is a slight broadening of the term originally coined by Fétis (in Reti 1958: p 7) due to the surprisingly diverse nature of tonality in MEM which does not always conform to the narrower definitions typically applied to classical music that deal primarily with chords and scales (Schenker 1935; Reti 1958) (Huron 2006: p 175). While it would be *possible* for examples of MEM to be described purely in these terms, in a significant number of cases, if this were the *only* focus, there would be very little to say, despite the obvious widespread appreciation of the music. In a similar way to the low information classification of EDM as simply “4/4”, it would be a vast oversight to declare that “minimal techno is drone-based” and leave it at that.

Despite the overarching influence of a western harmonic heritage, MEM producers, simply through using new technology and ignoring conservatoire knowledge, are often pushing the boundaries of traditional music practice. In such examples it is more revealing instead to explore atonicity (the apparent lack of tonic), tonal ambiguity, the subtle introduction of tonality through intuitively non-tonal voices, or the harmonic properties of overtones and their manipulation within a single note. At the other extreme, one might imagine the unnecessarily complex tonal analysis may be prompted during passages where a chord synth is played as though it were a lead (~2.22) – it would be simpler to treat the part as it appears to have been produced and perceived.

This would obviously involve a subjective judgement call, however the aim of this section is to describe enough of the tonality of MEM so as to convey an idea of the musical genre that is the providence of this thesis. It should not be construed as a theoretical attempt to authoritatively encapsulate all that is possible and denote precise generative likelihoods.

The current musicological literature on EDM (Keller 2003; Butler 2006) tends to revolve primarily around the rhythm, due to its importance, as discussed above. Literature on pop musicology does not often deal with “musical analysis” (Beard and Gloag 2005: p 11) so much as cultural theory (Hawkins, Scott et al. 2007) and when analysis does occur, tonality does not appear to be discussed in detail (Tagg 1982). As well as this, the musical interest in pop music is primarily in the vocals and this does not adequately relate to the more instrumental (non-vocal), repetitive and drone oriented styles of MEM. The analytical musicology of acousmatic and electro-acoustic

music also encounters problems of sonic analysis but to a much larger extent than MEM. While various approaches (Windsor 1995; Battier 2003; Hirst 2003) are somewhat relevant, there currently does not appear to be a framework for tonality that is suitable for MEM and so the following descriptive continuums were conceived, drawing from a variety of other music theories: rate of tonal change over time, the amount of recognisably pitched sounds, the level of harmonic coherence within the audible pitch set and the degree of polyphony.

I will explain these attributes and use them to define MEM. The objective here is to express the musical paradigm of the study and should not be construed as an attempt at defining music for any other purpose. Throughout the explanation of terms, I will present key examples from MEM and apply the descriptive tonal attributes to them in order to build evidence for the definition of MEM and express more of the genre through audible examples.

Rate of Tonal Change (Horizontal)

The rate of Tonal Change (TC) attribute relates to the level of activity within tonal parts – at one extreme, the entire track consists of a constant drone of tonic and/or pitch-set without changing over time (~2.88). A level above this we might observe drones that shift pitch only once in a whole track or at the end of a lengthy cycle (~2.89). A higher level of TC might involve typical chord progressions in the bassline such as the very common four-chord (~2.92) or two-chord (~2.93) varieties. Such progressions tend to gravitate to an underlying tonic (Bukofzer 1947 in Thomson 1999). At a higher rate still, the bassline could form a riff that dances around an implied fundamental bass (Grant 1977) or "Urlinie" (Schenker 1935/1979), an imagined bassline that can be reduced from notes over a span of time (~2.90; ~2.91). Above this level, we might consider lead riffs which are changing in such a way and at such a rate as to contribute to ambiguity of the underlying tonic. This is typified by the "solo" (~2.95). It should be noted that TC is derived from the sum of activity in the various pitched parts. For example in (~2.94) three voices can be heard: the bass that doubles the kick, the mid-high register synth fulfilling the role of bass, and the higher-register lead vibes, all different but adding up roughly to a mid level of TC overall – that is, the tonic and related pitches are not constant, but also are not so wildly variable as to confuse the tonality. Over the entire track the TC does not change dramatically. Having defined TC and provided an example of how it might be roughly gauged, it is now possible to examine how MEM can be described in terms of TC.

Overall, MEM is skewed more towards the "drone" end of the spectrum than the "solo", with most tracks consisting of two, three or four primary chords in a progression and many, particularly in EDM, consisting of a drone. The solo is, on the whole, a rare occurrence in MEM, although it occurs more commonly in sub-genres of MEM that are similar to pop music in terms

of structure and emphasis on the lead-part for interest, for example, the Portishead example above (~2.95). These observations apply to whole pieces of music, whereas if the time span is narrowed onto a particular section, the level of TC may deviate drastically. For example, during a fill section, there is generally an increase in TC either through transformation of a pitched part (~2.99) or addition of a pitched cue (~2.96), while during a breakdown the opposite is often true, due to the introduction of sustained pads (~2.97). In other instances ambiguity in the breakdown is partially conveyed through higher levels of TC in a kind of solo (~2.100). The tendency for MEM to have low to mid levels of TC, to be more "drone" oriented than "solo" oriented, can be contrasted with classical music which, with continual variation and key modulation, has a relatively high level of TC. Some might argue that EDM in particular should be listened to at the macroscopic level of the DJ's set and that at this timescale significant TC would occur. However, if one considers an orchestral work of the same length, it seems natural that the differences in TC between the two genres would remain. The broad genre of Pop music sits mostly in the middle, with complex lead elements and clichéd chromatic key shifts representing the upper boundary of TC and the more popular elements of MEM representing the lower boundary.

Tonal Stability (Vertical)

Tonal Stability (TS) is an estimate of how strong the sense of tonality (as tonicity) is, with primary reference to the tonic, but also to the idealised pitch schemas that the listener carries with them, for example, the minor and major scales. MEM has a mid-level of TS, but varies quite substantially. At the least stable end of the TC continuum, we could envisage pitches that do not suggest a particular tonic and do not relate to any of the scale intervals ever experienced by the listener. Above this, there may be recognisable intervals, but still no strong sense of tonic, as is often the case with whole tone scales. At the mid level, a tonic would be identifiable, but many of the other pitches may be accidentals or extraneous scale degrees that are less fundamental or less "similar" to the tonic. Above this, the tonic may be forcefully emphasised, featuring fundamental intervals such as the fifth, fourth and octave more strongly. The extreme of TS would feature only the octave.

One might ask: why are the intervals of fifth, fourth and octave given such a fundamental role in establishing tonality? Empirical qualitative research supports the claim that they are judged as "stable" and "strong" in musical terms (Huron 2006: p 145). The special fundamental role of these intervals is also apparent in the musicology of most other civilisations (Thomson 1999). These intervals are readily perceived as being similar on neurological (Weinberger 1999) and cognitive (Krumhansl 1979) levels. This also extends to the chords I, IV and V (Krumhansl 1983). On a physical level, the ratio of $2:3$ (the fifth), produces a shorter macro-cycle ($2*3=6$)

between the two frequencies than any other ratio below $1:2$ thus could be considered as something of a "best fit" on a physical level – while perfect ratios only exist in metaphysical realms, small inconsistencies in tuning, $2.03:3$ for example, are typically overlooked during tonal perception, an argument made earlier by Theodore Lipps in 1900 (Thomson 1999: p 89). Due to all of the musical, neurological, cognitive and physical reasons listed above, I consider music which features the octave, fifth and fourth intervals to have a higher TS over other intervals.

In opposition to this, one might argue "why is plainchant no longer popular if the perfect intervals are so important?". Firstly, TS is not synonymous with musical popularity, in fact, low TS is often used effectively to create interest, uniqueness or uncomfortable moods in MEM. Secondly, most popular music has an underlying harmonic movement that actually is based on perfect intervals, from the classic I-IV-V, I-V-I, the ii-V-I; indeed, even chromatically descending bass lines are often arranged as progressions of ii-V, ii-V, ii-V (a fourth). Even within the most remote tribal desert music that is apparently based on linear rather than logarithmic frequency intervals (Will and Ellis 1996), in Will and Ellis's Figure 2B, which displays a cumulative view of frequencies in the desert song, I have spotted ratios of a fifth between the most common pitch and third most common pitch and ratios of a fourth between the first and second most common pitch.

In addition to the perfect intervals, pitch-class-sets which are familiar to listeners will appear to have higher TS than those that are not. There is a lack of evidence for any particular scale with non-perfect intervals being more or less intrinsically viable from a musical perspective – that is, scales appear to be learnt (Thomson 1999), which is not to deny the evidence of certain affordances of the human mind to guide this learning, for example our propensity for five to nine discrete categories (Baddeley 1994). Because of this, from extended exposure to unfamiliar pitch-sets it is reasonable to assume an increase in TS for that pitch-set over time.

Within scales themselves, pitches have particular functions and can add to the TS by reinforcing a familiar pitch schema. Correlating surface pitches with **key profiles** is one way to assess the TS of a musical sequence and this formal approach is explained by Temperley (2007: p 53). Accidentals and pitches that are outside the dominant tonal schematic will also reduce the TS if they occur more often than is typical. This is supported by empirical music psychology studies which found that people have a notion that certain pitches fit a tonal context much better than others (Huron 2006: p 148), the individual judgements being averaged into a key profile.

As mentioned, MEM is considered as mostly having mid-level TS. This is justified as, in the vast majority, there is a clear tonic, regular scales are used, most commonly pentatonic minor, followed by minor and Mixolydian (major with flattened seventh). Tonal movement in chord progressions is often between I and V if binary (~2.104), or progressions that include V or IV if ternary or quaternary (~2.105). Sequences with lower TS have less "perfect" intervals in their

basslines or a copiosity of unfamiliar accidentals (~2.102). Tracks with higher TS are pure monotonic drones which span multiple octaves (~2.106). As with the other attributes mentioned, TS is dynamic, often changing during fills and breakdowns. As argued by Huron (2006: p 160, 161) and others, the sequence of pitches also contributes to stability, however the details would be a distraction to this current discussion. Nonetheless, the principal is exemplified here (~2.103) where a random-walk and arpeggio are played together, outlining a pitch-set, but not assisting in the definition of tonic.

In comparison, classical music can be considered to have mid-level TS for similar reasons, but deviating towards less TS rather than more, particularly when considering the more recent periods of tonal complexity. In contrast, pop music has mid-high TS, due to the prevalence of standard scales, chords, I-IV-V and fifth based progressions.

Pitch/Noise Ratio

The clarity of pitches has a direct effect on the ability of the listener to develop a sense of tonality – for example, in the case of total noise where there are no discernible tones, it is impossible to conceive of the TC (rate of tonal change) and TS (tonal stability). As a result, the Pitch/Noise Ratio (PNR) is considered here to be a relevant attribute of tonality, particularly for electronic music, which has always involved a significant amount of sonic expression. The continuum can be envisaged with purely untuned and/or distorted percussive sounds and noises at the lower end (~2.107). The highest PNR is music made from pure tones.

MEM overall has a mid range of PNR, but varying substantially between sub-genres and individual tracks. In particularly minimal instances, the percussive sounds are usually tuned in some way so as to suggest a basic tonality, or there is a very subtle application of tones, for example, the high-hat and kick (~2.108). In other cases, sound effects such as ring modulation are used to introduce tones (~2.109). In contrast, down-tempo artists such as Board of Canada are known for their rich tones (~2.112), although in the main sections these tones are usually accompanied by unpitched drums. Boards of Canada often “detune” their synthesizers, which provides a distinctive sound and does not obstruct the identification of tones. However, some other forms of pitch shifting can disturb pitch clarity and thus would have to be considered as having lower PNR (~2.111; ~2.110). Despite this, it should be noted that foreign and abnormal tuning systems are sometimes used, and these are not considered as having any less PNR due to the tones being quite perceivable (~2.113; ~2.114). A temporary decrease in PNR is often observed during fills, breakdowns and transitions, the dissolution of tonality being associated with increased tension or intensity. For example, DJ Shadow reduces the PNR through a record slow-down (~2.115).

The mid PNR of MEM can be contrasted with the high PNR of classical music; mid-to-high level of PNR in pop music; and the low level of PNR in acousmatic and electro-acoustic music. This is justified as most orchestral voices have a distinct pitch, including some of the percussive parts such as timpanis and triangles. In pop music, there is a heavy emphasis on tonality and pitch clarity and more conventional use of sounds than in MEM, mainly due to more conventional instrumentation and less emphasis on the electronic medium to assist expression. The sound-objects used to compose acousmatic and electro-acoustic music are often not easily recognisable as clear pitches and so have a low PNR. The PNR describes the clarity of tones for a given piece of music, while the TS and TC how these tones are organised to effect the tonality.

Number of Independent Pitched Streams (IPS)

The number of Independent Pitched Streams (IPS) relates to the number of pitched voices being perceived as operating independently and simultaneously. At the lowest end of the continuum is a single pitched voice/part, at the highest end is a dense texture built from numerous voices and in the centre is the typical three to five part tonal voicing of MEM and pop music. Usually there is one bass, one or two leads, and one or two accompaniments. Classical orchestral music can be distinguished by a high number of IPS.

While mid-level IPS is typical in MEM, there is often deviation from this, sometimes with extended periods of none (~2.107), one (~2.116), two (~2.118) and three (~2.117) or more voices.

A subjective judgement call is sometimes needed to determine whether a part contains multiple streams or not. As shown by Bregman (1990), a single sequence of tones, if played with alternating pitches that are related beyond a certain interval, it will be more likely to be perceived as two separate streams. Alternatively, a chord synth that always consists of the same chordal intervals in parallel might easily be classified as a single stream of an interesting ‘chord-like’ timbre (~2.22).

Structure and Form of MEM

Structural analysis of music is defined here as detecting patterns and trends on a macroscopic scale, while form deals with segmentation. Previous literature on musical structure has distinguished between three approaches: neutral, poietic and aesthetic (Nattiez 1990). The neutral approach is objective, the poietic is “emic” or oriented to the perspective of the producer, while the aesthetic is “etic” or perceptually and cognitively oriented. The approach taken here is primarily the latter, while being usefully informed by a poietic technological framework; that is,

analysing structure through the tools used to create it, for example MIDI sequencers. The aesthetic focus is appropriate because the primary aim of this section is to explain enough about MEM so as to clarify the musical genre of interest. The topic of musical structure itself is of less relevance to the note-level algorithmic concerns of the thesis than the other aspects of MEM that have been described, and so this discussion is accordingly less detailed.

The most useful approach to the analysis of MEM I have observed has been to represent each layer (kick, hats, snare, bass, etc) in the music on horizontal tracks that are stacked on each other with the presence of a loop in the layer provided in colour-coded (Hill 2005) or texture coded (Butler 2006) rectangular blocks. This macroscopic track layout visualisation is available to the producers of MEM through zooming out with sequencing tools.

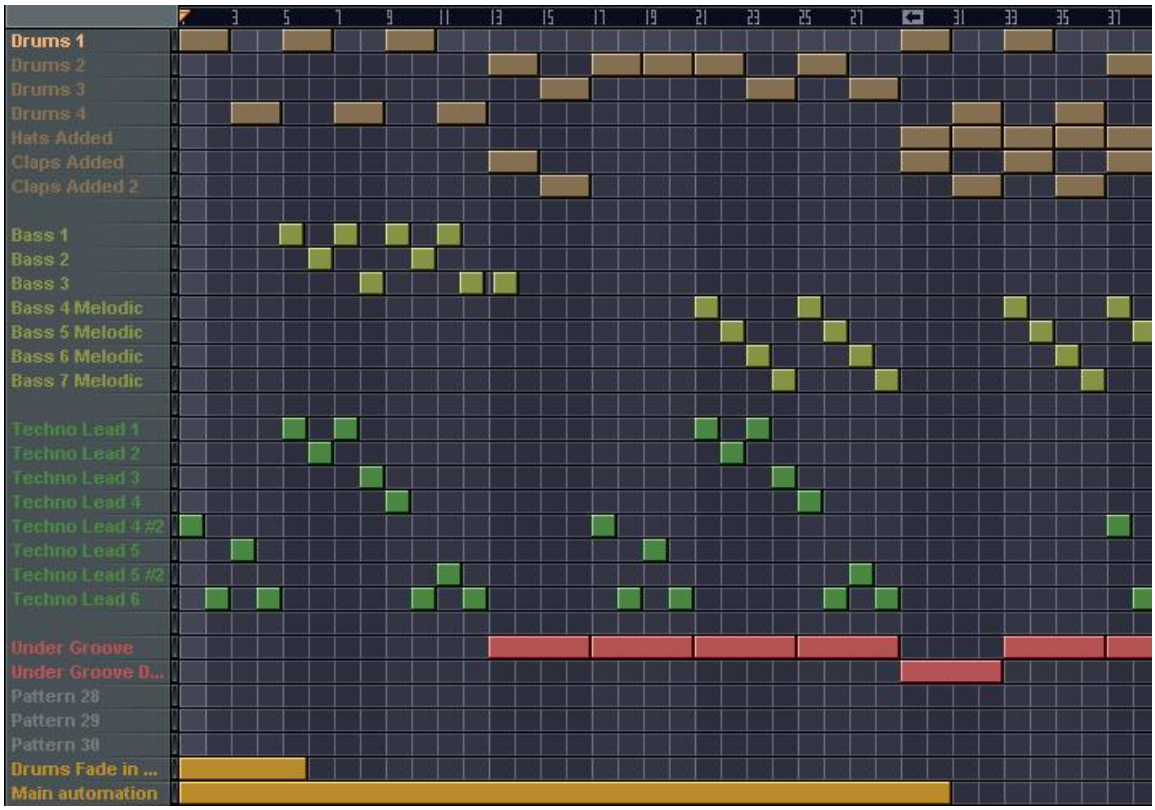

Figure 4 Screenshot of a macroscopic track layout from the *Fruity Loops* sequencer.

Other examiners of electronic dance music, such as Keller (2003), borrow from the structural analysis of classical music (Green 1979), drawing curves to represent the overall intensity and marking boundaries with thematic groupings.

MEM uses a wide range of structures depending on the context of the music. Butler (2006) makes an observation that is relevant to MEM:

> *"Form inheres within a number of different realms … On one end of the spectrum, there is the form of a single track, on the other, that of a complete set. Considerable variety exists within each of these categories: tracks can be experienced in their original versions as well as transformed and combined with other records, and sets can arise in live performance contexts or in the studio."*

I consider a similar structural continuum, from *continuous* through to *discrete* forms. Continuous structures are typified by the extended mix sessions of hardcore minimal techno where structural alphabetic segmentation (Whittall 2007) is particularly difficult and potentially fruitless. The music is continually shifting – as one layer is removed another layer is added. The music could be considered as a continuous bridge or mix with fairly consistent intensity. I previously likened this effect of sustained perceptual intensity to that of Shepard's tones (Shepard 1964) – attention is directed towards new layers, while the older layers are subtly removed, suggesting to the listener a continually increasing intensity (Wooller 2003). A DJ set is typically one or two hours, however the experience of music in a club is usually eight to twelve hours long (Butler 2006). Raves and 'doofs' (an Australian-style rave in the bush, typically featuring psychedelic trance music) often extend for longer periods, sometimes covering whole days.

Less hardcore dance music sets will include breakdowns that enable dancers to gather their breath. Although the music is continuous, there exists a clearly recognisable cycle of build-up, main sequence or further build-up followed by a breakdown. When I analysed *The Drum and Bass Arena* (Wooller 2003), I found there to be an average of 1.8 breakdowns per track.

More discrete forms in EDM become apparent when viewing individual tracks rather than complete sets. They are usually designed to be mixed and so the intro and outro are typically quite long (intro ~2.119, ~2.120; outro ~2.122, ~2.121 respectively). At the most discrete, where MEM overlaps with pop music, the music is built from contrasting themes that could be easily interpreted as fulfilling verse/chorus type roles. In this case the intro, outro and breakdowns are typically shorter.

2.1.2 Morphing in mainstream electronic music

Having provided a musicological overview of MEM in the previous section, I will now examine the current techniques and approaches to *morphing* in MEM. This review of existing methods will serve primarily as a point of reference for comparing the developments that emerged from the research but also as an inspiration to them and is thus directly relevant to the goals of the study as a whole. The review process involved searching online for acts of MEM morphery via peer-to-

peer, internet radio, music websites, discography databases, reviews, forums and communications with DJs and avid MEM fans.

A range of examples were found, from pure transitions, to morphs, to hybrids; however the compositional techniques used were extremely limited, particularly in the case of live electronic music. Mixes between pop oriented tracks, particularly those with distinct stylistic differences were perceived as "transitions". Mixes between tracks with compatible styles featured somewhat longer transitions that enabled a little hybridisation to occur. Extended mixes, more typical of EDM, were perhaps the most morph-like examples of existing MEM music compositions. The studio mixes that were found tended to follow the style of live mixes. Music generated by morph *algorithms*, rather than composer/producers, were also discovered, but are discussed in detail within the following chapter. The most prevalent practice related to morphing that I found in MEM was the remix, which clearly occupies the "hybrid" end of the spectrum. The techniques used in these examples tended to operate at the level of sampled loops, with most exceptions to this being in the remix. As a result, no clear compositional techniques for note-level morphing were found, although some trends regarding how loops may be combined became clear.

Music of the transitional type occurs in contexts where a variety of songs that don't necessarily fit well together must be strung together. Examples are pub or function/wedding DJs and, in some cases, computer game audio engines playing chart hits and/or certain pre-specified tracks. The transitions are usually very fast, so that the uncomfortable section in between the source and target is minimised (~2.123).

Live DJ mixing

Mixing tracks that are carefully selected and ordered is at the basis of EDM and Hip-Hop, which allows a greater sense of hybridity to enter the transition than would otherwise be coherent. The essential technique is cross-fading, which is typically an equal-power (logarithmic) fade-out from source while simultaneously fading-in to target.

Controlling where the tracks fade in and out allows the DJ to operate in temporal blocks – for example, foreshadowing chunks of the target track before the transition occurs (~2.124, where the warbling lead and "so twisted" vocals are from the upcoming track), substituting a fill from one record with the other and, obviously, enacting the transition itself. In conjunction with cross-fading, the source and target can be controlled temporally, rewinding or fast forwarding to particular points.

In addition to fading in and out, DJs have the ability to control volume at the bass, mid and treble for each track. This enables three layers from each track to be 'spliced'. For example, the bass

of the source layer might be cut, along with the mid and treble of the target layer – the resulting blend would be constructed from the bass of the target and the mid and highs of the source. While some DJs use external sound effects, computers and drum and bass synthesizers, the 'two turntables and a two-channel mixer' is typical. DJs may also 'scratch', though scratching is applied more as a percussive transformation rather than a way to integrate the tracks.

Harmonic tonal relationships in track selection

There is a trend within MEM for the transitions to exploit harmonic tonal relationships. EDM and Hip-Hop DJs will often select a target track with a tonic that is related to the source tonic by a fifth or fourth (EDM ~2.125, ~2.128; Hip-hop ~2.132), is a prominent pitch-class from the source and/or results in an interesting and coherent change in the harmonic function of various layers. Intervals other than the fifth or fourth are also often used during mixes. In this example from DJ Chris Scot (~2.126), there is a subtle layer that fulfils the intervallic function of 3-7-3. After the mix, which involves an upward tonic shift of a third, the function becomes 1-5-1. In (~2.127), the bell is first tuned to some higher octave of the tonic. During the transition the bass cuts, which is then replaced by new kick tuned to a fundamental that is higher than the previous bass by one whole tone. The bell remains tuned to its original frequency, but changes tonal function to a 7, due to the kick taking on the role of tonic. Scot goes on to shift down a major third (~2.129) in the same set.

Signalling the transition

As well as exploiting tonal relationships, DJs often also utilise other aspects of the source and target music to assist the coherence of the mix between them, such as cues and other structural features. A typical example is the breakdown, during which a degree of chaos is expected (~2.130). Cues enhance the coherence of the transition, typically through cymbals but also through interesting noises and even vocals. For example the spoken phrase "and I am out the door" acts as a cue during this transition (~2.131) providing an extra level of purpose or intention to the transition, as in, "yes I really am transitioning now – I am out the door and into the new track!".

Studio mixes of EDM

Mixing in the studio offers a greater degree of flexibility than live, however it does not, on the whole, appear to have been capitalised upon, especially within EDM. As remarked by Butler most studio mixes are treated as a "home-listening analogue to the live dance music experience" (2006: p 21) or as promotional tools for DJs and as a result the technical limitations of live mixing

are often carried over as stylistic limitations of studio mixes. There are of course exceptions, particularly when producers, accustomed to the range of studio techniques, create mixes involving source material (for example, MIDI files and synthesiser patches), typically from their own music. However, for EDM as a whole, the technological limitations of live delivery seem to direct the aesthetics of the music – a point which adds importance to the *interactive* (live) nature of this study.

Hip-hop mixes compared to EDM mixes

Hip-hop mixes appear less restricted than EDM mixes by stylistic criteria such as danceability, and as a result there is the potential for more complex forms of hybridity to appear within the music. With relevance to morphing, beat juggling is a technique where two records are inter-spliced live, along with scratching and other techniques. The “old-skool” Hip-hop philosophy places value on the live performance and physical virtuosity of **turntablism** (Toop in Shapiro 2000: p 96) shunning studio trickery, while the relatively newer Hip-hop movements take advantage of audio effects, MIDI and non-linear editing, more so than the typical EDM mix tape. However with the absence of generalised audio to MIDI conversion tools, application of sophisticated note-level techniques for integration of source and target in sample based music is rare.

Hip-hop producers tend towards audio appropriation while EDM producers tend towards synthesis, so an interesting conundrum exists for the case of EDM producers who mix their own music – Hip-hop producers are less able to create note-level transitions (for example, extended key modulation) between their own, sample-based music, while EDM producers, despite often being eminently capable, often adhere to the style of live, audio-based mixing. If the new techniques for live, note-level morphing developed through this research were widely available, this situation might change.

Computer game music

In a similar way to live and studio mixing, computer game music must also deal with transitions between tracks, however in cases of in-house composition, the task is made somewhat easier due to the fact that music can be composed specifically to be compatible during transitions. Devices already mentioned such as transposition by fifths, half-time and double-time, and layer splicing are used (Electronic-Arts 1998; Apple 2006). Other techniques include changing timbre and note-sequence independently (Rare 1998), changing chord progression and scale, as well as composing bridges when necessary (Fay, Selfon et al. 2003: p 390; Sanger 2004).

Remixes

At the hybrid end of the spectrum are remixes, which range from using only a crucial snippet from the remix subject and composing everything else around it, to simply modifying the speed and adding a complementary layer. Remixes are considered as creative works in themselves and often more of a *variation* of one track rather than a merger of two. For these reasons they cannot be considered as morphing in the truest sense. The range of possible techniques is as extensive as music production itself, and there are no particular remix techniques which stand out as being particularly relevant to morphing.

Aphex Twin is well-known as a remix artist, with releases such as *26 Mixes for Cash* (James 2003) while many prominent EDM producers have been invited to remix the pop singer Madonna. Some artists release their master tracks for free or in competitions to encourage exposure, for example Fat Boy Slim's *Star 69*. Other artists are remixed without invitation, for example The Rolling Stones in *Paint it Blacker* by Plan B (~2.136).

While remixing typically "frames", enhances or pays tribute to the original, the more subtle use of sampling and recontextualisation appears more generally throughout MEM and this can also be thought of as hybridisation. For example, the Fugees superimposition of a 6/8 classical guitar loop from *Requierdos De L'Alhambra* over a breakbeat to create the distinctive mood of *Family Business* (~2.61), is considered more of an act of sampling than a "remix". Frank Zappa uses the term **xenochrony** to describe the juxtapositioning of different layers from different recordings (Michie 2003).

Mashups

The underground (not for profit) remixing and bootlegging of 'mashups', 'blends' and 'bastard pop' music is a seemingly huge unmapped area of MEM (Anonymous 2007). Typically these involve the A Capella vocals of one source over the backing from another. *The Grey Album*, mashed by Dangermouse, was a popularly acclaimed (Gitlin 2004) and controversial (Synthtopia 2004) mashup restricted to only two sources of musical input – *The White Album* by The Beatles and *The Black Album* by Jay-Z. Because of this restriction, it seems at first to be particularly relevant to source-target style hybridising that is the topic of this research, although it is more a case of sample recombination from the whole of *The White Album* being applied to create a backing for each track of the Jay-Z A Capella rapping, a layer which remains unchanged (~2.147). Dangermouse's detailed approach to sample recombination allows fresh compositional ideas to be constructed from the original Beatles material. Overall however, the mashup genre seems to rely on humorous or otherwise interesting juxtapositioning rather than musical

ingenuity and the techniques used, such as layering, are, from a musical perspective, fairly standard. This is not to belie the ingenuity which occurs on the level of audio manipulation - isolating vocals, cutting, pasting, recombination and DSP.

Stylistic combination

At the level of patterns and styles, hybridity, or “syncretism” has some basis in many, if not all, acts of music composition that attempt to fit with a known style, and particularly with the creation of new styles and new compositions from old. There are too many examples to list, but in a MEM context there is the influence of early European electro in early Hip-hop (~2.135), the mixture of dub, soul and hardcore dance in jungle and drum and bass (~2.134), and the influence of classical harmony in tonal EDM (~2.133).

Summary of mainstream electronic music and morphing

MEM, as described above, is the musical paradigm within which this research is based. Defining features of the style were described, such as the construction of music from loops of various lengths and layers with various roles, and the emphasis on repetition and rhythm. In particular, BB, with emphasis on the backbeat and irregular rhythms; and FF, with emphasis on the regular, steady downbeat; were explained through various theoretical lenses. The tonality of MEM was analysed through a framework of attributes that consisted of rate of tonal change, pitch/noise ratio and number of independent pitch streams. The structures of MEM were also briefly explained.

Following the musicological investigation of MEM, attention was turned in particular to occurrences of morphing, with live mixing appearing to be the most widespread and notable of these. Although such approaches are widely practiced, it was observed that various technological limitations and aesthetic habits afford only certain forms of hybridisation to occur when transitioning. It is the goal of this research to create technology that enables new, much less limited musical morphing to occur easily.

Motivated by this, the next chapter is an investigation into musical contexts outside of MEM, in order to glean applicable compositional techniques as well as providing a backdrop against which the outcomes of the research can be framed.

2.2 Morphing in other musical contexts

The previous section described MEM and how it related to morphing, which was important for clarification of the musical context under research. This section will range further afield and

present particular aspects of other musical contexts where morph-like situations have occurred. All of the examples discussed relate to *semi* or *un*-formalised compositional approaches, while formalisations that are explicit enough to be algorithms are discussed in the following chapter.

Analysis of the wider musical context in relation to morphing was important to the research, primarily serving as inspirational material from which relevant ideas could be combined, modified and re-contextualised into MEM. As well as this, it provided a backdrop from which the new techniques could be compared.

As mentioned previously, morphing is conceived as a combination of transitioning and hybridisation and the examples within this section are organised accordingly, from transitions (2.2.1), morphs (2.2.2) to hybrids (2.2.3). The discussion of transitions deals with medleys that switch directly from one song to the next, as well as the arranging techniques that are used to ensure a smooth transition. The section on morphing, although necessarily limited, covers a range of influential works and theories that are directly relevant to morphing. Acknowledging that hybridisation holds a fundamental role in the creative process, discussion of this aspect is mostly limited to techniques which draw from specific musical-surface sources such as **centonization**, **quodlibet** (and the plethora of related terms), as well as newer examples that extend outside these fairly historical categories. However, there is also a discussion, necessarily brief, on syncretism, as it relates to the hybridisation of musical style.

A number of interesting musical techniques have emerged from this review of morphing outside of MEM, while the historical and contemporary coverage of “hand-composed” morphing is comprehensive enough to meaningfully position this research within the wider musical context.

2.2.1 Transitions

Outside of MEM, transitions between pieces of music, movements, and themes are a common occurrence. Transitions are defined as when the interval between the two segments is so short and structured in such a way that no convincing sense of ‘hybrid’ can emerge. Compositional techniques for enabling a smooth transition include matching the source and target, signifying the transitional event as well as reinforcing commonalities and differences when appropriate. Medley is the technique of stringing together pieces into a continuous sequence, dating back at least to the sixteenth century (Grove 2007). Many such medleys involve a sequence of simple transitions. Any forms of music with contrasting themes, such as sonata, must also transition between each of the themes. Saslaw (2007) discusses “direct transitions” in key modulation, where the key simply changes, as well as “sequential” modulation, where a phrase is restated in

the new key. Bridging techniques and more sophisticated key-modulation techniques invoke notions of hybridity and so are dealt with in the section on morphs below.

A simple and effective approach to transitioning is to match the source and target as closely as possible, thereby reducing the disorienting impact of the change. This involves matching virtually every dimension of music, including tonality, rhythm, pace, timbre, dynamics and so on. For example, in "polka power!" (~2.138) by Weird Al Yankovic, we can observe consistency in instrumentation/timbre, dynamics, vocal, chord, accompaniment and rhythmic styles ("oom-pa"), as well as small distances in the key changes. The first transition is typical of pop music – within[2] *Wannabe* by the Spice Girls, the song switches from minor to major in the transition from verse to chorus and the tonal centre shifts to the dominant (~2.139). As well as this, the lead vocals change from unpitched to pitched. Changing from minor to major in verse and chorus is common enough in pop music for it to be perceived as a coherent shift, rather than an unexpected clash. The tonic and dominant are closely related, as discussed previously, and so shifting from one to the other also contributes to the smoothness. The transition following this, to *Flagpole Sitta* by Harvey Danger, incorporates foreign material (polka clichés) as a bridge, which, in my opinion, serves to partially erase the echoic memory of *Wannabe* (~2.140). The tonic shifts down by a whole tone. The transition from *Flagpole Sitta* to *Ghetto Superstar* by Pras Michel (~2.137) shifts the key down another tone, while the subsequent transition to *Backstreet's Back* involves another disrupting polka cliché bridge before shifting down by a minor third to the relative minor (~2.141). The medley adheres more or less to this formula the whole way through. Similar principals are involved in other medleys, such as in bag-pipe music (~2.142), with consistent tonality and instrumentation providing unity despite the abrupt transitions. Medleys that feature greater hybrid integration of source and target are considered in the following section on morphs.

While matching the source and target obviously reduces the distance between them, a substantial degree of 'transitional shock' can be acceptable if it is framed appropriately. This involves punctuation, earmarking[3] (Cope 2005) and/or cues – signs that invoke an awareness of musical structure, alert the listener to upcoming changes or reinforce the sense of purposefulness surrounding the new change. As discussed previously, cues include variations or transformation of patterns as well as particular sounds such as cymbals. Within classical music, the distinct slow-down at the end of a phrase communicates the upcoming boundary and, at

[2] Within this song, not between it and any other.

[3] The 'ear' in earmark has no particular musical meaning – it is a form of identification, such as goats that are identified by *marking* their *ears*. A motif can be earmarked by a cymbal crash.

such a juncture, changing to a new and contrasting segment of music is quite acceptable and to some extent expected (Huron 2006). As well as this, cadences can be used both to mark the end of a passage (Huron 2006) and reinforce the tonality of a new one (Schoenberg 1978; Schoenberg 2006). A cadence that includes I-IV-V has the useful side-effect of highlighting all the pitches in the scale, while a I-V-I includes all but the sixth.

To summarise the discussion of transitions, the most important musical decisions are made in the selection and arrangement of the source and target so as to be similar. Additional techniques are bridge sections, cues and cadences. Bridges can utilise pivot chords and notes to emphasise similarity or incorporate unexpected material in order to 'wipe the slate clean' and prepare the listener for the target. Cues indicate change, while cadences reinforce the changes in tonality.

2.2.2 Morphs

While transitions achieve a degree of coherence through matching the source and target and providing contextual cues, a more powerful, smooth, or at least interesting transition is often sought by the composer, through some kind of bridge that reinforces commonalities and/or has properties reminiscent of both source and target. This means that some kind of hybrid combination inspired from source and target is occurring during the transition and thus it is considered to be a kind of morphing. Musical examples and theories of this type abound and so the discussion is necessarily limited to some of the most influential ones. This includes theories of key modulation, temporal modulation, transitions over musical topologies, the practice of folk music medleys and some key examples of sound morphing. While there are no doubt many more examples worthy in some way of comment, this coverage is detailed enough to provide a range of techniques and a broad, multi-perspective backdrop to the research which, after all, is primarily focused on *automated* techniques and *MEM* in particular.

Key Modulation

The modern understanding of modulation, as a clear change from one key to another, arose in the 18th century, while it was through the widespread chromaticism of the 19th century that theorists and composers began to rigorously investigate key modulation as a theory and technique (Saslaw 2007) and as a result there is now a substantial body of literature.

Schoenberg (in Muzzulini 1995) conceived key modulation as having three sections: A, B and C. A is in the original key of the source, but "neutral triads" (triads with the thirds tuned to be half way between major and minor) are played (presumably on a violin or similarly flexible

instrument), so as to weaken the tonality of the source key. During B, the key changes to the target but “pivot root progressions” are used to mark the turning point. At C, a new cadence is used to establish the new key. Schoenberg (2006) also referred to Anchluss-Technik, the “joining technique”, likening key modulation to the fixing of wooden boards together at cross-grains giving the wood “adaptive forms” and/or using nails, screws, or roughening the ends and gluing. He also sees “condensation” as a useful modulation technique, bringing elements closer together in terms of harmony, rhythm, melody and dynamics.

In general, pivot chords are constructed from the bisection of the source and target pitch class sets. The key distance, as indicated by the number of common pitch classes shared by the source and target keys, therefore governs what pivot chords are possible (Saslaw 2007). In 1774, Johann Kirnberger published the text *Die Kunst des reinen Satzes in der Musik (the art of strict composition in music)*, which included some suggestions for “quick modulations”, involving three steps from the tonic to five different keys – D minor, E minor, F major, G major and A minor (Ferris 2000). The general principal is to shift to a pivot root pitch that is related by a fourth up or fifth down to the new tonic. Obviously, the aforementioned keys are all quite close to C in terms of key-distance, which makes the task fairly easy.

Within Arabic music, modulation between modes is of central importance to the music (Marcus 1992) and the “gradual” types are particularly relevant to morphing (Marcus 1992: p 178). Arabic music theory distinguishes between modulations that involve a shift of the tonic, and modulations that involve a change of mode, without a shift in tonic. In modulations that shift tonic, it is common to shift at an interval of a fifth, fourth – that is, “the note that starts the original mode’s upper **tetrachord**” (Marcus 1992: p 177). It is also possible to shift to the third and sixth degrees. A technique to effect subtle tonal change is to shift to the upper tetrachord of the target mode mid-phrase, thus holding off the more unambiguous tonality of the lower tetrachord until the melody descends again (Marcus 1992: p 178).

In his discussion on Irish national music, Travis (1938) pointed out a number of modulation scenarios in ancient Irish tunes that were similar to this, as well as others that were not, such as modulating between major and parallel minor and modulating to major and shifting tonic by a major second. Modulating by a fourth has been noted in Japanese Shamizen music (Tokita 1996). Changes in “non-nuclear” tones (not of the “nuclear” fourth tones) also occur (Tokita 1996), similar in concept to parallel major and minor modulation. As well as this, the source and target **tetrachord** can be layered into a composite scale (Tokita 1996).

The role of the fourth and fifth interval in modulation is also apparent within Jazz, where modulation is often achieved through cycles of ii-V-I. Iterating this pattern a number of times enables any key to be reached from any other key. For example, changing the tonic chord from

major to parallel minor changes the function from I to ii without shifting the root pitch. While the function ii is not immediately apparent, the shift from ii-V-I, which *does* involve a change of root pitch, then serves to cement the new tonality. Russo (1968) touches on this technique when discussing modulations through the V_7 of the new key. He also mentions use of the common (pivot) chord, "direct assumption" of the new key and "modulation through scale movement", where a scale from the source or target is juxtaposed against the key.

Western theorists that followed Kirnberger examined how to achieve more obscure and difficult key changes, for example Bernard Ziehn in 1888 published techniques for changing to any key through application of nine types of modified seventh chords (Seargent 1933; Saslaw 2007). The advantage of seventh chords is that inversions can be achieved fairly smoothly, providing a close connection between four possible roots. With chords that have the property of symmetry, such as the diminished seventh, inversions can be made without changing the function. Max Reger (1903) published a collection of examples that used pivot chords to modulate from C major to 41 different keys (including double flats, double sharps). Travis (1938) points out that while ancient Irish harpers are likely to have used complex tonalities compromising dissonant chords with three, four or five pitches, the music that survived imperialism achieves modulation through melodic variation rather than chordal complexity. Other techniques for modulation to difficult keys include chromatic alteration in the middle of a phrase as well as emphasising only one or two 'pivot notes', notes with pitches that are common to both tonalities (Saslaw 2007). This technique is also employed in Arabic music (Marcus 1992: p 189).

More recently Muzzulini (1995) developed an algorithm to generate pivot root progressions with the properties of inner symmetry, however works with this degree of algorithmic formalism are reserved for discussion in the following chapter.

Temporal modulation

While key-modulation occupies a central role in western music theory, the concept of modulating from one metre, tempo or rhythmic pattern to another is examined less often, and usually only in the avant-garde. Two distinct issues seem to occupy theorists: 'tempo' or 'metric' modulation; and 'beat-class' modulation or 'rhythmic interpolation'. The former concerns the techniques to effect a smooth transition from one tempo or rate of play to another, while the latter deals with the problems of interpolating particular rhythmic patterns.

Tempo modulation (or metric modulation), is defined as a transition from one tempo to another through a common sub-pulse. No comprehensive theory of tempo or metric modulation exists, although it has recently come under closer scrutiny (Benadon 2004). More than a century and a half prior, in 1832, Fétis speculated that:

> *"Someday, someone would do for rhythm what had been done for harmony and melody: find the essential transitional element that would admit rhythmic modulations into music"*
>
> (Arlin 2000)

Twenty years on, both Fétis and other theorists such as Hauptman, were publishing material with the assumption that *"… philosophic principals underlying metric structure are the same as those underlying the harmonic structure of tonality"* (Lewin 1981) and applying this assumption to analysis of the musical examples of the time.

However, while there is some justified speculation that, for example, composers such as Brahms were applying tempo modulation to composition in the latter quarter of the nineteenth century through hemiola (Lewin 1981), clear examples of 'tempo modulation' only came much later in the work of Elliott Carter, notably in *Variations for Orchestra* (1954-1955). Carter himself is unconcerned with the task of formalising his compositional process (Carter 1960). Fernando Benadon recently (2004) formalised some aspects of tempo modulation. He pointed out the need to somehow limit the set of possible pivot ratios but offered no particular criteria other than notational complexity and performance difficulty:

> *"for example, a modulation such as 'dotted eight-note quintuplet equals sixty fourth note' is conceivable but probably impractical"*
>
> (Benadon 2004).

More importantly, Benadon presented a useful formula for calculating the number of possible tempos given the number of pivot ratios and the number of steps (discrete changes in tempo) that are required for the modulation. In his example, the pivot set is arbitrarily limited to the six ratios between each of three, four and five (triplets, quarter notes and quintuplets).

While tempo modulation deals with bridging different pulse rates that share some common ratio, it is a different problem again to consider how to modulate smoothly from one rhythmic *pattern* to another, regardless of the pulse. Essentially the problem comes down to how the *discrete* rhythmic values can be mapped into a *continuous* space. As will be discussed in more detail in the following chapter, Max Mathews (1969) interpolated rhythmic patterns by first converting the inter-onsets into a continuous function, while Daniel Oppenheim (1997) paired notes together in various ways and interpolated the onsets of the individual notes. The problem is explored to some extent in the phasing of minimal music, where polyrhythmic beats cycle in and out of phase. If we consider "in phase" to be the source and "out of phase" to be the target, the intermediate rhythmic patterns (sampled at any regular interval) can be considered as a kind of

morph between them. The music of Steve Reich, notably “Piano Phase”, is iconic of this technique. Analysts of Reich’s music, beginning with Warburton (1988) and then Cohn (1992) used the notion of **beat classes** to describe the rhythmic pattern that eventuates at the point where it is maximally out of phase. Callender (2004: p 39-41) identified a variable that can be calculated from the beat class set and sampling interval over time that, he argues, relates directly to the ability of the listener to predict the rhythmic patterns of the next sample. In analysing more recent and less metrically confined works of Reich’s, Roeder (2003) extended the notion of beat classes to deal with the effects of accent and pitch on the perception of beat classes.

Topological transitions

There have been many notable attempts to conceive of musical spaces which, once formed, could be used to compose music through navigation of the topology. This notion is relevant to morphing, which would be equivalent to moving along some trajectory between two points on the topology.

Polansky (1987) explored the notion of metric distance between patterns in a number of performance contexts. Of particular relevance to morphing was a piece called *Drawing Unnecessary Conclusions*, where each performer would pick a pattern and draw it on their screen. They would each then pass that pattern to the person on their left and make incremental modifications of their own, until it matched the pattern they had been passed. This is as clear an example of ‘hand-composed’ morphing as could be found, however it is difficult to garner information as to the specific techniques used, due to the improvised nature of the performance.

Roger Shepard (1982) developed a model of tonal pitch space which relates well to perceived pitch relationships, by combining musical pitch dimensions: Circle of Chroma (CC), the Circle of Fifths (CF) and linear pitch space, resulting in a double-helix torus (see Figure 5).

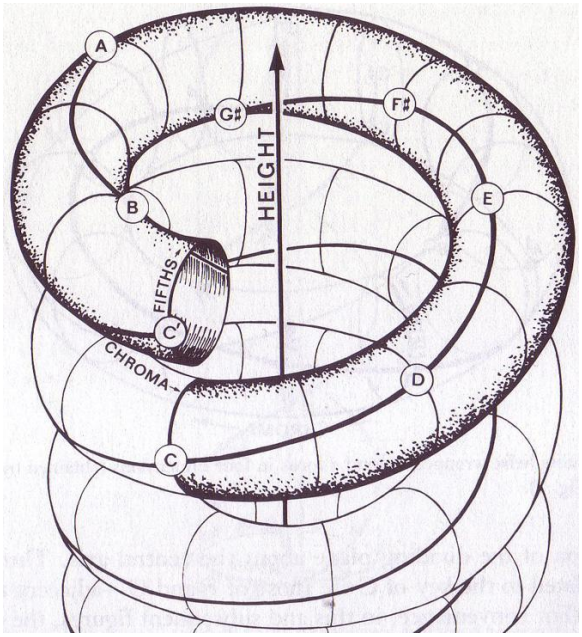

Figure 5 The CF combined with the CC and linear pitch space[4]

Shepard's representation was adapted for use in the *LEMorpheus* software (which I developed for this study), with weightings governing the influence of each dimension in the space.

Guerino Mazzola, has created a substantial body of work in German relating to topologies of music, covering harmony, melody and rhythm, and it has been compiled into an English publication (2002). As with Muzzulini (1995) and Noll (2001), it is computationally explicit and thus relevant to algorithmic music. Callender (2004) uses formal descriptions of trajectories through spaces of particular distance metrics to analyse music that contains continuous transformations. Tenney (1979) explored notions of distance between temporal gestalts, while Rosenboom (1982) used topological concepts to inspire his compositions.

A number of examples of 'morphing' from the western chamber music repertoire also can be perceived as continuous interpolations along various loosely conceived dimensions, as noted by Oppenheim:

> *"the opening to Beethoven's 'IX Symphony' is a transition from chaos into order. The second movement of Berlioz's 'Harold in Italy' gradually morphs from the 'Harold' theme into the 'procession' theme, as a procession is portrayed moving towards, and then away from, the listener. Ravel, in 'La Valse' gradually morphs from chaos into a Viennese waltz, and then back to chaos."*

[4] Reprinted from (Deutch 1982: p 364) with permission from Elsevier Limited (copyright holder).

(Oppenheim 1997)

Cage's *Metamorphoses* (1938) might be added to this list, as well as Hindemith's *1943 adaptation of Weber themes* (1989), and Philip Glass's *Glass Cage* variations of Cage's piano pieces (2000).

Without doubt, a huge number of other composers occupy this territory, however, for the purposes of outlining some important and relevant aspects of the musical and theoretic background, the overview provided above is sufficient.

Extended medley and similar notions

As mentioned previously, **medley** is the technique of stringing together themes into a continuous sequence and while many medleys involve rapid transitions, many others utilise more sophisticated bridges and are thus more relevant to the notion of morphing. The practice is particularly widespread in folk music. "Medley overtures" relate specifically to the technique being applied to opera and operettas, while borrowing themes from a range of sources. Medley is employed as a means to achieve continuity and danceability in live performance, for convenience, humorous effect, to consolidate the emotional impact of disparate themes, demonstrating musical cleverness and skill, and possibly other reasons.

Overall, medleys that are popular seem also to have the source and target music well-selected and well-arranged as discussed in the section on transitions above (2.2.1). There does not appear to be a comprehensive catalogue of the more complex compositional techniques, although some have briefly commented on approaches:

> *"Examples in the 'Fitzwilliam Virginal Book' regularly repeat each tune in a varied form, and one of the vocal medleys surviving from the 16th century is built on an ostinato bass"*
>
> (Grove 2007)

Jigs, reels and marches of Celtic and Gaelic music are commonly strung into medleys to effect continuity. The musical form of individual pieces themselves are also often a sequence of unique themes, for example ABCDEFG (Travis 1938). As with the *Fitzwilliam Virginal Book*, variation (Travis 1938) and alternating the varied themes from source and target is the prevalent morph-like technique for bridging the transitions. For example, a phrase from the source verse might be varied by changing to the new mode, before switching back to the chorus and then fully into the new verse. This is effectively a kind of "tonal foreshadowing".

Operetta and musical medley (Grove 2007) such as *The Phantom of the Opera Medley* by Andrew Lloyd-Weber and *The Medley from Les Miserables* by Claude-Michel Schönberg, and the blending of Disneyland themes into medleys (Sides 1996) has the effect of binding separate emotive experiences together into a more powerful whole, which, particularly in the case of the latter, also serves to reinforce brand power.

Alongside medley appears a raft of other similar historical practices. The more motley potpourri dates back to 1711 (Wikipedia 2007), which literally means “rotten pot”. The techniques used in potpourri appear less sophisticated, designed primarily for humour. The quodlibet (literally “what you please”) is the classical version of **mashup** or **xenochrony** and is sometimes also used to refer to medley. The term has been used since 1544 (Maniates, Branscombe et al. 2007) and seems to provoke a similar sense of low-art distain as potpourri.

Other, even more obscure, musical formats similar to medley, potpourri and quodlibet in historical music throughout Europe include:

> *“fricassée (France), misticanza or messanza (Italy), ensalada (Spain) … farrago, rôtibouilli, salatade, fantasia, capriccio, pasticcio, and miscellany”*
>
> (Maniates, Branscombe et al. 2007)

However, rather than exploring the minutiae of cultural deviations, it is sufficient for the purposes of this section to observe that morphing has a substantial number of precedents in historical music.

Sonic morphing

While this research is primarily concerned with the note-level, morphing one sound into another is of tangential relevance, due to similarities in the overall form of the compositional objective. Explicit sonic morphing can be heard in modern orchestral music, early tape music and is now a widespread practice in digitally produced music.

Oppenheim notes the role of sound morphing in orchestral music:

> *“In modern music the concept of morphing was broadened and applied to entire sonic environments; the first movement of Pendercki's ‘second string quartet’ is a morph from non-pitched, short, noise-like percussive material into sustained notes with a definite pitch.”*
>
> (Oppenheim 1997)

Other examples of this include Ligeti's *Athmospheres* and *Apparitions*, as well as Xenakis' *Metastasis*.

Typically, however, more flexible and unusual sound morphing can be achieved through mediums that afford direct representation and playback of sound. Trevor Wishart, in the sound art classic *Red Bird* (1973-1977), explored sound morphing using studio tape editing techniques (~2.148). As with DJ mixing, selection of source, target and intervening material was important, as evidenced by the effort with which the large bank of recordings were carefully catalogued and labelled with a framework of morphological terms (Wishart 1996), so that Wishart could "find the correct bit of tape on the correct reel when (he) needed it" (Wishart 2000). Cutting and pasting (with razor and glue), mixing, filtering, pitch/time stretching, fading and recording techniques were also used.

Many other sound-artists such as Francois Bayle, Guy Reibel (Oppenheim 1997) and Alejandro Viñao (1996) have employed sound morphing for artistic effect.

Sound morphing can nowadays be conducted through DSP rather than manually, and some of the techniques that are used for this are mentioned in the following chapter on algorithmic music and morphing (chapter three).

2.2.3 Hybrids

Hybridity in music occurs on a number of levels, from the musical surface through to more abstract notions of musical style. Optimally, I was aiming to find instances of hybridity that directly utilised the musical data from two specific works, in the style of source and target, as this would involve similar techniques to those required by compositional morphing algorithms. However I was unable to find examples in which this was the case. Despite this, many composers are renowned for appropriating and recombining the work of others, composition students learn a range of techniques that have been developed by others and the drive for musical innovation leading towards new styles through a blend of existing ones is fundamental. The blending of musical style from two or more different cultures is sometimes referred to as musical 'syncretism', a term adapted from religious notions of syncretism, originally by Waterman (1948) and later applied to ethnomusicology by Meriam (1964). Hybridity in music is arguably as old as music itself however for the purposes of this discussion the scope is necessarily limited to a few examples.

Centonization is a technique of hybridisation through recombinant composition applied to Gregorian plainchant (Chew and McKinnon 2007). It involves the arrangement of a number of segments of chant, according to various rules. Within the boundaries of the plainchant style, the

centonized compositions are hybrids of the various plainchant songs. As opposed to other methods of musical patchwork such as the quodlibet, the juxtapositioning is not intended for humour and it seems to have garnered a little more respect from some (Chew and McKinnon 2007: p 85).

David Fanshawe's acclaimed *African Sanctus* is also inspired from church music but hybridised with recorded samples of traditional African music. Choral orchestral and drumming elements that are played live are harmonised with the pre-recorded African music (Fanshawe 2007). Other examples of syncretism between African and European music and the techniques used are documented by Jim Chapman (2006). A more contemporary example African-European hybrid is *Lambarena* (Courson and Akendengue 1996) which weaves the rhythms, textures and timbres of Bach with traditional African music.

Hungarian composer Bartok was renowned as a synthesiser of styles and freely admitted to appropriation from an eclectic range of Hungarian, Transylvanian, Romanian and Slovak folk music that was the subject of his ethno-musicological work. Clear elements of appropriation include scales, rhythms, melodies and harmonies (Bartók 1950; Gillies 2007). Bartok also noted that other major composers such as Stravinsky must either engage in similar practices or somehow be gifted in the creation of folk music by themselves, due to the evidence of peasant music styles in their music (Bartók 1950: p 22). Later on, Schnittke coined the term "polystylism" to describe similar tendencies in his own practice and that of other composers of the time (Schnittke 1971).

These examples, while blending musical style, frame the cross cultural music within predominantly western contexts such as seated chamber performance and audio recordings. It is plausible that the reverse might occur – for example, playing western style chamber music outdoors, continuously over a number of days, with community participation and dancing – however, this is rare. While the nature of hybridity as it exists within the post-colonial paradigm might seem fairly one sided, more recent inventions of EDM culture, speculatively, are at the forefront of a reversal (Brewster and Broughton 1999).

Overall, techniques for hybridising music vary considerably and remain far from formalisation. Despite this a continuum can be envisaged, at one end being direct quotation and appropriation, the other end involving the use of higher-level musical constructs such as musical form,metre, scales, harmony, instrumentation and voice roles. This is related to Chapman's categories of appropriation (Chapman 2005), which range from "borrowing" through "assimilation" and "**syncretism**" to "abstract conceptual appropriation". Although music theories in general seek to explain why and how certain patterns might be seen as "coherent" or "interesting" within a particular style, there appears to be very little music theoretic work on what it takes for a

particular instance of appropriation of any type to fit well with a particular context. Composers of hybrid music determine what works through emic means such as experimentation and/or musical intuition, while theorists appear unable to derive precise etic explanations. Doing so would require more general theories of music that are able to resolve differences within each of the elements within the hybrid and theories of such generality are more related to music psychology than music theory and thus more difficult to apply to music composition practice.

2.3 Summary of music and morphing

MEM is the primary genre addressed by this research and it can be defined as a popular electronic instrumental practice involving the layering of loops. Typical roles of the layers include percussion, bass, accompaniment, lead and sound effect. Cues, which can occur in any layer, are used as structural signifiers. Often the roles are ambiguous and may change over time.

Rhythm in MEM is particularly important and a number of techniques are used by composers to play with the sense of beat. Metre is understood as an abstract rhythmic pattern that is used as a reference point when listening and is constructed from patterns that are both ingrained and learned. Within MEM, two fundamental metric patterns are evident – FF and BB. FF explicitly emphasises the beat, while BB does not and can be interpreted in a number of ways, including polyrhythms, additive rhythms, syncopation, beat roles and transformations. Hypermeter, as the pattern of emphasis over longer, macrostructural time-spans is suggested by the placements of cues.

Tonality is the sense of importance attributed to various tones. Despite the importance of rhythm in MEM, the approach to tonality is sometimes surprisingly complex and requires a new set of terms. I divide the tonality of MEM into four dimensions: TC, TS, PNR and IPS. TC is the rate at which the tonality changes, from drone through to unpredictable solo. TS is the degree to which the music emphasises fundamental tone and tone set, from perfect intervals through to intervals that obfuscate the tonic. PNR is the degree to which tones themselves can be distinguished, from total noise to pure tones. IPS is the number of independent streams of pitch that can be distinguished by the listener.

Structure and form is an important part of MEM, defined through the build-up and breakdown of tension over the entire length of the track. A pragmatic view of structure and form is obtained through the production tools used to create and arrange the music. Structure and form are of little relevance to this research however, which deals with segments of MEM rather than entire pieces.

Morphing is apparent throughout a number of MEM compositional practices including live DJ mixing, studio mixes, computer game music, remixes and mashups. DJs working within a variety of genres tend to select source and target music so as to exploit harmonic relationships when mixing. Producers and composer make similar decisions that involve not only the selection, but also the arrangement and manipulation of source and target music. Transitions are enhanced by appropriate cues. Style combination is another related aspect of MEM composition, however as it is abstract rather than explicit, it is more difficult to formalise and thus apply to this research.

Musical contexts outside of MEM also have relevance to morphing. Simple transitions between source and target are often witnessed in medleys and through direct modulation of keys. More complex techniques for integrating the source and target that are more relevant to morphing include indirect key modulation techniques, temporal modulation, topological transitions, extended medleys and sonic morphing. Hybridisation of music occurs through a continuum from direct appropriation through to synthesis of musical style and practice.

Collectively these examinations of morphing in various musical fields showed that while much material existed for inspiration, there were many opportunities for novel and applicable research to formalise and recontextualise current compositional techniques, extend musical possibilities and allow new forms of adaptivity through compositional morphing. This review covered a fairly broad swathe of music and music theory, and theoretic formalisations were mostly at the level of natural language. Complementarily, the following chapter reviews relevant theories and systems that are so explicitly formalised as to be executable on a computer.