UNDERSTANDING THE NEED FOR MICRO-GESTURAL INFLECTIONS IN PARAMETER-MAPPING SONIFICATION

David Worrall
School of Music, Australian National University,
Building 100, The Australian National University,
Canberra ACT 0200, Australia.
david.worrall@anu.edu.au

ABSTRACT

Most of the software tools used for data sonification have been adopted or adapted from those designed to compose computer music, which in turn, adopted them from abstractly notated scores. Such adoptions are not value-free; by using them, the cultural paradigms underlying the music for which the tools were made have influenced the conceptualization and, it is argued, the effectiveness of data sonifications.

Recent research in cognition supports studies in empirical musicology that suggest that listening is not a passive ingestion of organised sounds but is an embodied activity that invisibly enacts gestures of what is heard. This paper outlines an argument for why sonifiers using parametric-mapping sonification should consider incorporating micro-gestural inflections if they are to mitigate The Mapping Problem in enhancing the intelligibility of sonified data.

1. INTRODUCTION

Western art music became increasingly conceived as a complex-patterned time-ordered series of disembodied acoustic events that vary in pitch, loudness and timbre; that are absorbed and elicit emotions when listened to. This paradigm is embedded in scored compositions that are abstractly composed and realized by expert musicians in concert or rendered to a recording medium for transmission to listeners.

Classical cognitive science follows a long philosophical tradition in the West that posits consciousness as the means by which knowledge is acquired. Computer music, which developed alongside and intertwined with classical cognitive science in the second half of the twentieth century, has also been heavily influenced by the ‘acoustic event’ paradigm, and has embedded it in many of the software tools used to create it. These tools have been widely adopted by data sonification researchers who use them in an attempt to obtain a better understanding or appreciation of relations in datasets of varying size, dimension and complexity.

2. MUSIC COMPOSITION AND DATA SONIFICATION

While data sonifiers and music composers share a common need to render structures and relations into sound, their purposes are different and so is the evaluation of the sonic results. It is useful to distinguish data sonifications made for the purposes of facilitating communication or interpretation of relational information in the data, and data-driven music composition, ambient soundscapes and the like—the primary purpose of which is artistic expression and other broader cultural considerations, whatever they may be. The current use of the term “sonification” to include such cultural concerns is unfortunate because it blurs purposeful distinctions. Maintaining these distinctions is not to suggest that there are not commonalities–the two activities can provide insights that are mutually beneficial. However, because the purposes of the activities are different, so will be their epistemological imperatives and consequences, such as, for example, in tool design, usability and evaluation.

Music and musical listening involves whole complexes of social dimensions that are simply not relevant to the perceptualisation of data relations. Though music may be composed of syntactic structures, there is no universal requirement that these structures be made explicit, even aurally coherent. In fact, stylistic or even dramatic considerations may require the exact opposite, in the orchestration of spectral mixtures by melding of instrumental timbres, for example.

There is no one-way to listen to music; different musics require different ways of listening. Data sonification in which the user-driven real-time exploration of datasets using dynamic scaling in multiple dimensions, perhaps with auditory beacons [1] may not result in musically coherent sound streams. Even if listened to *as* music, data sonifications may provoke critical commentary about issues such as the appropriateness or formal incompleteness of the resulting sonic experience. Perhaps, as Polansky suggested, the closest point of contact between pragmatic data sonification and musical sonification is in compositions in which a composer intends to ‘manifest’ mathematical or other formal processes [2]. This ‘classical’ motivation is explicitly enunciated by Xenakis, for example, who exemplifies the process for several compositions in detail [3][4].

While many composers use mapping and other algorithmic techniques of one kind or another in their compositions, they are rarely interested in ‘featuring’ the mapping explicitly. Nor do they use mapping in order to simplify the working process or to improve production efficiency, but in the emergence of musical forms. In order to gain a deeper insight into the way composers map conceptual gestures into musical gestures, Doornbusch surveyed a select few composers who employ the practice in algorithmic composition [5].

> *I am not interested in projecting the properties of some mathematical model on to some audible phenomena in such a way that the model be recognized as the generator of some musical shape.* [5].

So, those interested in producing music of a certain complexity may shy away from simple mappings, as they can be hard to integrate with other musical material of a substantial nature. On the other hand, as Larry Polansky explains,

> *...the cognitive weight of complex mappings degenerates rapidly and nonlinearly such that beyond a certain point, everything is just 'complex'* [5].

Even a suitably complex, structurally coherent mapping may not be musically sufficient if the composition relies on a (human) performer, as composer Richard Barrett emphasizes:

> *In a score one is always dealing with the relatively small number of parameters which can be recorded in notation, and which interact with an interpreter to produce a complex, 'living' result.* [5].

The importance of this embodied 'living' aspect of music has often been forgotten, ignored, or even dismissed in Western art music. The next section explores some of the historical reasons for and consequences of doing so, and argues that such an approach to data sonification is likely to have a major impact on the intelligibility mapping-encoded artifacts.

3. SOME TRENDS IN WESTERN MUSIC

3.1. Notation

In Western art music, notation evolved, along with the notion of "the Work" [6] from a performer's *aide de' memoire* to a tool of thought for defining works of increasingly abstract complexity. Notated scores came to be thought of as the encoded representation of sounds, even as a somewhat definitive objectification of a composer's thoughts. That we (at least in English) so frequently substitute the word 'note' for 'tone', 'music' for 'score', exemplifies the strength of this conceptual elision.

In a number of intricately notated works of the twentieth century, it seems the performer is sometimes considered an unfortunate necessity. In others, notation functions as encapsulated stimuli by which the performers, as they attempt the impossible task of playing it "note-perfectly", enact a drama of physical and mental exertions. This idea is integral to many of the works of Kagel, Berio, Ferneyhough and Xenakis, for example. Theodore Adorno noted a tendency to consider the bodily presence of the performer as a kind of contamination of musical experience as a manifestation of a commodity fetishism where the

> *…immaculate performance … presents the work as already complete from the very first note. The performance sounds like its own phonograph record* [7].

3.2. Electronic and computer music

Before the commercial availability of tape-recorders following the Second World War, a considerable amount of energy was applied to the creation of electrical musical instruments, not infrequently with the aim of producing theatre organs that could reduce the numbers of performers needed for music-making to accompany theatrical productions and silent films.

The inherent instability of analog electronics meant that exactly reproducing electronically produced sounds was well nigh impossible. When digital computers eventually became available, they were celebrated for the ability they had to generate sounds that were exactly the same: On time, every time. F. Richard Moore, one of the early pioneers put it like this:

> *… improvements in electronics technology allowed serious composers of the 1950s to begin the exploration of new types of "synthetic" sound as material for music…*
>
> *What, then, is significantly different about computer music? ... the essential quality is one of temporal precision. Computers allow precise, repeatable experimentation with sound. In effect, musicians can now design sounds according to the needs of their music, rather than relying on a relatively small number of traditional instruments* [8].

3.3. Music as a recording

It was not uncommon for early composers of electroacoustic music to consider the lack of the need for performers as one of their motivations for working in the medium. In conversation, Tristram Cary, one of the early pioneers of the genre, frequently spoke enviously of sculptors, who could create works that exist as objects in their own right, without the need for interpretation by performers. In the passage, notice also how Cary has the instrument doing the playing, rather than a performer:

> *For composers of an exploratory turn of mind, the most frustrating limitation of normal instruments is* ***their inability to play*** *more that a few selected pitches with each octave. ... The notion of realizing music as a recording rather than as a performance seems to have grown almost simultaneously in the minds of a number of individuals, myself included, during the Second World War* [9]. (my bold).

3.4. Musique concrète

In contrast to the 'abstract' notational approach, some composers assembled musical 'gestures' directly from recordings of 'concrete' sound objects: complex sound phenomena, originally captured with microphones and tape-recorders, in real world of physical objects and processes.

A number of different approaches can be identified: at one at one end of the spectrum there is Pierre Schaeffer's reduced listening abstraction (which I discuss in more detail, below) and at the other, mimetic discourse or aspects of human culture not usually associated with musical material [10][11]. Examples include Murray Schafer's soundscapes and other works of the acoustic ecology movement. A sort of 'middle' position between abstract sound and mimetic discourse, on a continuum between real and unreal that also includes the surreal [12], can be found in the works of Luciano Berio (*A-Ronnie*) and Trevor Wishart (*Red Bird*). Wishart himself writes in some detail about relationships between sound images to develop not only sonic structures but a whole area of metaphorical discourse' [13].

Although reduced listening was originally intended by Schaeffer as a method for investigating the typo-morphology of sounds themselves, it influenced the rise of acousmatic[1] music which was specifically composed for loudspeaker presentation; the work existing solely as fixed audio recordings and often intended for concert reception via multiple loudspeakers alone.

3.5. Sonorous objects and reduced listening

Pierre Schaeffer was interested in establishing ways by which concrete sounds could be composed into musically meaningful continuities. Schaeffer was heavily influenced by Edmond Husserl (1859-1938), a seminal philosopher of perceptual phenomenology who developed the method he called *epoché* or "bracketing'. E*poché* focuses on those aspects of our intentional acts and their contents that do not depend on the existence of a represented object "out there" in the extra-mental world. "Bracketing" is methodological constraint on phenomenological description. It is undertaken from a first person point of view so as to ensure that the item being described is described exactly as is experienced, or intended, by the subject. Husserl was concerned with only what was experienced or intended not whether the phenomena actually existed (they might be hallucinations or perceptual errors). Because it is not possible to fall victim to and detect a perceptual error or misrepresentation at the same time, all perceptions are of transcendent objects that appear to constitute themselves in consciousness. So any object of attention that arises from the intentional acts of the perceiver must be "bracketed" from any assumption of the correctness of any assumptions of existence of the object [14][10].

In order to develop a methodology for composing with tape-recorded concrete sounds, Schaeffer applied this idea of "bracketing" by encouraging composers to consider sounds as intentional objects i.e. as they appear to constitute themselves in consciousness, reduced of any assumptions concerning their existence; reduced of any connection or association with anything, real or imaginary, from which they might have arisen [14][15].

The desire to find a means of ordering "found" sounds as musical material led Schaeffer to develop the notion of a *sonorous objects,* holistically perceived fragments of sound typically in the range of a few seconds or less which afford the apprehension of the fragments as a shapes, that is, as features independent of their identifiable sources [16][17]; what Smalley calls their "source bonding" [18]. Schaeffer considered sonorous objects as intentional units [14: 263]; that form somewhat stable images by a process Miller called chunking [19]. Such sonorous objects had the potential, given certain criteria were met, to become *musical objects*.

3.6. Spectro-morphology

Smalley's spectro-morphology was originally intended as a descriptive tool based on (a composer's) aural perception because

> *…composers need criteria for selecting sound materials and understanding structural relationships. So descriptive and conceptual tools which classify and relate sounds and structures can be valuable compositional aids*. [20].

Spectro-morphology "is primarily concerned with music which is partly or wholly acousmatic," and is "intended to account for types of electroacoustic music which are more concerned with spectral qualities than actual notes…"

Smalley considered the term "spectro-morphology" to be the natural successor of the Schaefferian term 'typo-morphology' as well as being a better description [21: 220]. Although this claim has been questioned [22], its acceptance probably has more to do with the lack of an English translation of the *Traité* than any enunciation of a convincing argument. Nevertheless, what was considered an important advance in "…the non-vernacular fork of the musical language…" [21:61], was a reduction to the spectral domain and this is in keeping with the firmly established trend towards a musical intelligence based on disembodied cognition.

3.7. Time scales in music

An important task of musical composition is the management of the interaction of various types of structures on different time scales. Roads identifies nine theoretical levels [23] of which the most relevant are

- Macro. The overall duration of the musical form, measured in minutes, hours or in extreme cases, days.
- Meso. Groupings of sound objects into (musical) hierarchies, measured in seconds or minutes.
- Sound Object. The duration of individual notes (tones or textural complexes) measured in fractions of seconds or, in extreme cases, minutes.

With the advent of computers, composers had control of a greater temporal hierarchy than previously possible, including

- Micro. Durations that extend down to the threshold of auditory perception, measured in milliseconds.
- Sample. The atomic level of digital audio systems in the form of individual amplitude levels that follow one-another at fixed time intervals, measured in microseconds.

[1] The term *acousmatic* was borrowed from Pythagoras who was believed to have tutored his students from behind a screen so as not to let his presence distract them from the content of his lectures [10]. Presumably his non-visual (vocal) presence vocally was not considered sufficient to establish his actual presence.

3.8. Commentary

The idea that music is (just) the sound of music is embedded in much of Western music. Recall, for example, Edgard Varèse's definition of music as "organised sound". Furthermore, the combination of the following characteristics indicates a firmly Cartesian mindset:

- The evolution of notation from an *aide de memoire* for performers to the abstract 'definitive' documentation of a piece of music 'against' or 'to' which performer's react.
- The making of compositions using sculpturally 'fixed' sounds, often synthesised of physically measurable parameters (frequency, amplitude, duration, spectrum, location etc) and performed by electro-mechanical means.
- The use of construction processes that focus on perceptual properties of sounds have been intentionally abstracted from their means of production.

Just as many composers of notated music thought of the performer's unreliability in being able to exactly reproduce the score was an undesirable 'feature' of performance, so also did composers of electroacoustic music think that the inability to reproduce analog electronic sounds was undesirable. These composers welcomed digitalisation because it brought a much-desired feature to electroacoustic music: reproducibility.

There is no logical reason to assume that the ways composers organise their sonic material needs to be the same as the way listeners listen to it–especially if, in order to do so, they need to apply a 'bracketing' of the material from the common associations that it may invoke. However, the desire to emphasise the abstract features of sound material, reducing it to the formal properties of its spectra, does abstract its gestural potential away from the subtle feedback mechanisms involved when a cohering sound stream is created corporally.

4. Listening

4.1. Schaeffer's musical listening/musicianly hearing

In his *Traité*, Schaeffer's goal was not just the codification of his 'reduced listening' methodology for describing sounds, but the development of a musical syntax that incorporated a wider range of sounds than those available through traditional instrumental resources in short a typo-morphology of (immanent) musical objects. In doing so, he makes a distinction between musical listening and musicianly hearing.

> *Generally speaking musical listening or invention refers back to traditional heritage, to established and accepted structures and values, which it attempts to rediscover or recreate; whilst musicianly hearing or invention seeks rather to locate interesting new phenomena or to innovate in the facture of sound objects. The musical attitude rests on old values; the musicianly attitude actively seeks new ones* [24: 39].

So when an arpeggio is played, for example, a musical listening will recognize a pitch structure that can be split into various objects coinciding with its individual tones, whilst a musicianly listening will discern a single sonic object–a minor chord arpeggio.

4.2. Other modes of listening

Schaeffer's recognition that there were two ways of listening was unusual for the time and even today, empirical studies dealing with music listening and perception rarely explicitly address *how* sound is listened to. Listening is an active process and further consideration reveals that there are more ways of listening than Schaeffer's "musical" and "musicianly".

Since they explicate an understanding of how meanings can be conveyed in effective design, taxonomies of listening modes have been considered as useful tools in the field of sound design [25]. A review [26] reveals several other approaches to such a taxonomy and in a recent update [27] it is suggested that there are nine modes, each of which constitutes a different meaning-creation:

Reflexive: A quickly evoked, innate action–sound reaction affordance based on an automated (or 'hard-wired') schema due to the evolutionary adaptation to our ecology.

Kinaesthetic: An imaginative gestural sense of motor-movement, arguably based on unconscious processes that manifest innate or early developed schemata concerning bodily movements, coordination and postures. It appears likely that musical listening contains different levels of imitative effort related to the experience of body movement.

Connotative: Active projections of action-relevant values as resonances of conscious or learned schemata based on natural and/or cultural constraints.

Causal: The intention to recognize (features of) the source of sounds (as auditory icons, for example).

Empathetic: Perceiving and signifying affective states that could signal someone's emotions and intentions inferred empathetically from body gestures.

Functional: Context-oriented listening focused on the purpose of sounds.

Semantic: The intention to recognize sounds as signs that stand for something due to socio-culturally shaped and learned codes (as earcons, for example).

Reduced: The intention to divorce the phenomena of sounds from their everyday contextual meanings so as to attend to the qualities of sounds themselves (after Schaeffer).

Critical: Reflective self-monitoring in order to verify the appropriateness or authenticity of responses given the context.

If sonifiers were more aware of which listening modes they expect listeners might employ when using their sonifications to obtain information, it is likely to assist in the achievement of their goal to create explicit meanings. In order to do so, sonification research needs to develop specific techniques to address listeners in these various modes. This will require a different focus from that used for the creation of sounding objects (whether through parameter mapping, interactive models or other techniques), to the development of a rich assortment of modes of excitation, interaction and presentation.

5. GESTURE AND SONIC OBJECTS

5.1. Embodiment

There is a growing recognition among music researchers that, notwithstanding that occidental art music today encompasses a wide range of motivations and listening practices, and that the abstract reductionism practiced has enabled an unprecedented level of complexity, the conveyance of this complexity is reliant, at least to some extent, on embodied interpretation for effective communication.

It was not until it was technically possible to construct musical compositions without the assistance of embodied interpreters that it was possible to meaningfully speculate on the extent to which a listener's perception of the structural characteristics of a piece of music are dependent on the sound-encoded gestures of performers, and not just the notated score. This has the unfortunate consequence that if sonifiers follow the musical trends outlined above, which most have been apt to do, the intelligence that is recognised as embodied is not 'available' for use; at least not explicitly, through the available software tools.

> *For many centuries, people learned to listen to sounds that had a strict relation to the bodies that produced them. Suddenly, all this listening experience accumulated during the long process of musical evolution was transformed by the appearance of electronic and recorded sounds. When one listens to artificially generated sounds he or she cannot be aware of the same type of concrete and mechanic relations provided by traditional acoustic instruments since these artificial sounds are generated by processes that are invisible to our perception. These new sounds are extremely rich, but at the same time they are ambiguous for they do not maintain any definite connection with bodies or gestures* [28].

In a later reflection on the intelligibility of his spectro-morphological approach, Smalley agrees but couches it in terms of the limitation of the listener:

> *[...] we can arrive at a situation where the sounding spectro-morphologies do not correspond with perceived physical gesture: the listener is not adequately armed with a knowledge of the practicalities of new 'instrumental' capabilities and limitations, and articulatory subtlety is not recognized and may even be reduced compared with the traditional instrument.* [29: 548].

5.2. Gestural-sonorous objects

Godøy's and others' research on musical gestures suggests that there are gestural components in the mental recoding of musical sounds [30][31]. Godøy extends Schaeffer's idea of the sonorous object (3.5, above) to gesture. In developing his concept of the g*estural-sonorous object*, he found considerable evidence to support the hypothesis that when we listen or even just imagine music, we trace features of the sonorous objects heard by hands, fingers and arms etc.

> *This means that from continuous listening and continuous sound-tracing, we actually recode musical sound into multimodal gestural-sonorous images based on biomechanical constraints (what we imagine our bodies can do), hence into images that also have visual (kinematic) and motor (effort, proprioceptive, etc.) components* [16].

These intentional objects 'chunk' at meso- and sometimes micro- timescales (3.7 above), and there is simultaneous perception at the macro-level such that a succession of such chunks does not disrupt the experience of the continuity, even though the attentional focus may be discontinuous.

The association of body movement with music appears to be is universal and independent of levels of musical training and in 'sound tracing' studies there seemed to be a significant agreement in the spontaneous drawings of gestures that people with different levels of musical training made to musical excerpts [17]. This work as been extended to include a solution for recording data and media in a synchronized manner, different types of analysis and visualization strategies, and, given there seems to be no publically available databases of music-related body motion data, a classificatory scheme for music-related actions that includes classification by both corporeal action and sonic features [31].

6. PROPRIOCEPTIVE INTERFACES

6.1. Gesture

Much research to do with physical gestures in the performance of music has concentrated on understanding and generating the role of extra-notational aspects of music, particularly on emotional expression and affect [31]. Godøy identifies several applications of the analysis of sound-related actions, including composition, improvisation, musical performance, music education and rehabilitation, musicology and music information retrieval, as well as in music technology [17].

Musical instrument designers have taken up the call for more 'embodiment' in computer music as a call for better interactive tools for computer performance. The now ready availability of cheap, gestural controllers, including generic "smart-phones", has resulted in a wider acceptance of technology-mediated live music performance [32], and gestural controllers have found applications in interactive sonification, such as by providing means to interact with data-derived resonator models in model-based sonifications [33][34].

6.2. Haptics

Most research on the use of human gestures in music and sonification production have concentrated on interactive control interfaces that employ gross corporeal-scale gestures such as arm waving. However, professional string players know that much of the art of playing is in bow control and percussionists know that the different characteristics of a bass drum, say, are revealed not only by whether it is struck, scraped or rubbed by wood, felt, rubber or metal of various sizes and densities, but by the subtly of those actions. Thus, given the choice, percussionists will choose to use their personal collection of beaters and other 'interface instruments' on borrowed instruments, over the reverse.

This suggests that, while an analysis of the gestures employed in interacting with sonification models should provide valuable insights into improving their design, such research needs to be extended to include the development of a diverse means through which the energy in such gestures is conveyed to resonators; not only a wider range of modes of excitation (hammering, stoking, rubbing, squeezing etc) but considerable improvements in the sensitivity of haptic interfaces [35][36]. Furthermore, as exemplified by the fact that musicians frequently employ physical gestures in order to better control their haptic interface with resonant objects [31], for proprioceptive control of sound, it is erroneous to treat physical gesture and haptics as psychophysically independent[1].

6.3. Micro-gestural inflections and protensions[2]

Micro-gestures are typically those that require small, often covert, physical gestures, such as those that occur at haptic interfaces. They are mechanisms of the perception-action cycle and are regarded as a basis for musical expressiveness and cognition [38]. Studies reveal that such micro-gestures are aurally 'available' to listeners, albeit subconsciously (e.g. [39]).

7. IMPLICATIONS FOR PARAMETER-MAPPING SONIFICATION

The investigation reported in this paper originally began as a search for solutions to The Mapping Problem [40][41]. In parameter mapping sonifications (PMS), parameters or features of the data, are mapped to sound parameters: either to physical (frequency, amplitude), psychophysical (pitch, loudness) or perceptually coherent complexes (timbre). PMS is recognized as a valuable sonification method, because of its flexibility and the high number of acoustic attributes available The main limitation of PMS is co-dependence, or lack of orthogonality (linear independence) in the psychophysical parameter space: parameter interactions can produce auditory artifacts that obscure data relations and confuse the listener. Further, the range and variation of such effects can differ considerably with different parameters and synthesis techniques.

Typically, PMSs consist of elementally composed soundpoints (or spectral complexes) that are assembled in the hope that the psychophysical continuity of at least some of its parametric dimensions integrates the perception of those sounds into a single immanent object or perceptually coherent auditory scene. In the absence of an inherent 'system' synergy to integrate these spectral complexes, any holistic conflation has to be achieved by the listener alone. Artificial reverberation is often employed to try to provide some spatial-binding. The simplistic uniformity of the result often just provides a mushy melding, which is rarely convincing and at worst, anti-soniculate [42].

PMS owes its conceptual origin to the "notation-executing performer" model of music that it inherited through computer music composition software in which the performer is replaced with a software synthesizer. The sometimes algorithmically generated computer music score has been replaced by a parametrically mapped dataset.

With acoustic instruments, the necessity for a player to continuously input physical energy means that they are actively engaged in a tight feedback loop; controlling the modulation of all the parameters of the sound in a complex of cross-couplings within a resonating physically-integrated object. In could be argued that the fact that parametric synthesis works as well as it often does for music is probably more due to the embodied intelligence of the performer and the cognitive ability of the listener than the robustness of the technique. This suggests the following improvements:

1. The use of more complex virtual instruments such as physical models that temporally integrate and cross-modulate parametric inputs over both space and time.

2. Better synthesis tools

   > *... for the generation of incrementally different variants of sounds, allowing systematic exploration of morphological features, e.g. minute control of various aspects of grain and mass...*[16].

3. More sophisticated sound activator models that provide sophisticated affordances between gestural and haptic controllers and sound synthesis/transformation.

4. A computational model that transforms the data-driven parametric inputs to the sound synthesis engine with human micro-gestural inflections.

8. SUMMARY AND FUTURE WORK

There is a growing body of evidence to suggest that much of what is understood when listening to complex sonic structures such as music is related to the ability to unconsciously 'mirror' the corporal actions of the performer/activator and the physical nature of the resonators on which they act. Performers are known to alter the manner in which they realize musical ideas based on a complex integration of the structural importance (e.g. agogics) and the physical limitations of both the musical instrument and their own physiology. These constraints and gestural inflections are encoded in the sound production and available to listeners through audition alone.

A detailed examination of micro-gestures and protension is beyond the scope of this paper however it may be vitally useful as a basis for understanding how to encode a data sonification into a more holistic psychophysical continuity or perceptually coherent auditory scene. It is thus suggested that an empirical

[1] This is nowhere more evident than in a considerable amount of the research reported at NIME (New Interfaces for Musical Expression) conferences. See http://www.nime.org/.

[2] Anticipations of future events.

study be undertaken to examine the effect of incorporating micro-gestural models in the process of transforming data structures to sonification mapping parameters. This is a non-trivial task but would be made more manageable through collaboration with those empirical musicologists who are analyzing and classifying the micro-gestural and haptic content of the action-perception cycles of musical performances, particularly that content which reveals musical protension.

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