Suggested Applications of Musical Improvisation Analysis to Sonification

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ABSTRACT

This paper presents an overview of a framework for analysis of performer interactions in improvised music (Pelz-Sherman 1998) and suggests some potential applications of this framework to the field of sonification.

1. INTRODUCTION

Analysis of performer interactions in improvised music has important applications to several areas of sonification research; in particular, improvisation analysis can provide helpful strategies for extracting structural information from sonifications of complex, multi-agent systems, and for hearing interactions within multi-dimensional datasets. It can also provide guidelines for production of sonifications that are amenable to such analysis. A wide variety of techniques exist for converting data into sound; however, the process of extracting meaningful information from sonifications is not well understood. Just as traditional tonal musical analysis (Forte et al, 1982) can reveal common organizing structures in tonal music, new theoretical frameworks can help analyze the products of both free improvisation and sonification.

1. CONTEMPORARY IMPROVISED MUSIC AND SONIFICATION

Sonification inevitably involves aesthetic choices, and the line between sonification and art is indistinct. Indeed, some researchers consider sonification design itself an act of musical composition (Bargar, 1994). The work of composer John Cage - whose aesthetic philosophies laid the foundation experimental music - is an important precedent here (Nyman, 1999). One of Cage's most important innovations was the establishment of techniques of "indeterminacy" or chance operations as an accepted part of contemporary compositional practice. Cage's works include several pieces that could be seen as early examples of data sonification, notably *Atlas Eclipticalis* and *Etudes Australes,* in which Cage mapped star charts on to a musical staff to derive his pitch and rhythmic materials. Other composers have used sonification techniques to produce artwork, for example Charles Dodge's "The Earth's Magnetic Field" (Nonesuch H71250, 1970), or Bob L. Sturm's "Music from the Ocean" (http://www.composerscientist.com/).

Several sonification designers have attempted to introduce stylistic elements of western classical music into their designs through various mapping techniques – for example, the Mt. Etna volcano sonifications done by the Musica Inaudita group at the University of Salerno (http://grid.ct.infn.it/etnasound). Other sonification designs employ traditional jazz styles, notably the "WebMelody" project, also from the University of Salerno (http://wonderland.dia.unisa.it/projects/SONIFICATION/). Researchers have claimed that such mappings can facilitate the perception of "periodical patterns, regular behaviors, and long-range correlations" in data, and that this approach improves listeners' "ability to perceive rhythmic, harmonic and contrapuntal interactions and relationships" between channels (Roginska, Childs, and Johnson, 2006). A common thread in all of these works is the notion that converting data into "music" will reveal to the ear something interesting and/or beautiful that was not easily detected by the eye, or impossible to represent graphically.

Advances in computer music technology have made it almost trivial to transform data into music using straightforward mapping techniques. I believe however that there is a "missing link" in this process – namely, a recognition that sonification is a fundamentally new kind of music, requiring new ways of listening and thinking. This paper is an attempt to begin filling that void. Since traditional concepts of musical structure do not apply to music created through sonification, we must expand our concepts of sound organization to better conform to the phenomena of interest.

Contemporary improvised music shares many important features with the products of sonification, in particular, sonification of the behavior of complex, interacting, multi-agent systems. In fact, improvised music can be seen as a sonification of just such a system. Examples of shared features include:

- Chaotic/unpredictable metrical/rhythmic structure
- Chaotic/unpredictable harmonic organization
- Complex, dynamic texture with multiple overlapping streams
- Prevalence of noisy/complex timbre, pitch, and rhythmic material

There is a central distinction between traditional music composition and free group improvisation. In Pelz-Sherman (1998) this distinction is characterized by the terms "monoriginal" and "heteroriginal," the former referring to creative work that is the result of a single mind, the latter, work that is the product of multiple, interacting intelligent agents. Free improvisation is a direct manifestation of processes operating and interacting spontaneously, with no pre-determined structure and no central source of control.

Traditional sonification, like monoriginal composition, has tended to focus on creating an optimal blending and balancing of multiple sounds or sonic parameters (Kramer 1994). The emphasis of much sonification work to date has been on combining and balancing the aggregate parts into easily "digestible" compositions. Heteroriginal music, by contrast, emphasizes and optimizes the voice of each individual performer. In this music, the interaction of the individual agents is placed in the foreground, rather than their sonic aggregation or combination. The specific notes and their vertical relationships are less important than the horizontal flow of information between agents. This decentralized view of musical structure has cultural as well as musical implications, as musicologist Christopher Small has observed:

> *It is a characteristic of tonal-harmonic music that it requires a high degree of subordination of the individual elements of the music to the total effect. Not only is the progress of each individual voice required to conform to the progression of chords, but also each individual note or chord is meaningless in itself, gaining significance only within the context of the total design, much as the authoritarian or totalitarian state requires the subordination of the interests of its individual citizens to its purposes. It is therefore interesting to see in the music of those British colonies which become the United States of America a disintegration of tonal functional harmony taking place long before such a process became detectable in Europe, and it is not too fanciful to view this as one expression of the ideal which, however meagerly realized or even betrayed during the course of its history, has never quite disappeared. (p. 129)*

It can be argued that most interesting phenomena in the natural world involve multiple interacting causes or forces, and can therefore be described as "heteroriginal" in nature. Therefore, developing a deep understanding of the processes and structures informing heteroriginal music should be excellent "ear training" for sonification analysis. As UC San Diego assistant professor and author David Borgo writes, "a better understanding of the workings of improvisation, how musical techniques, relationships, and interactions are continually refined and negotiated in performance, can provide insight on how we understand the dynamics of the 'natural' world and our place within it" (Borgo 2006, p. 1).

2. AN IMPROVISATION ANALYSIS FRAMEWORK

During my graduate studies in UC San Diego's Critical Studies and Experimental Practices program (http://music.ucsd.edu/grad/csep.html), I developed a framework for analysis of performer interactions in contemporary improvised music (Pelz-Sherman, 1998). The abundance of talented experienced musicians in this program willing and able to act as subjects offered an ideal environment for researching how this music is constructed and organized. My framework was the culmination of several years of research under the guidance of noted improviser and musicologist George E. Lewis, Psycho-acoustician Gerald J. Balzano, and composer Rand Steiger. Research techniques included transcription and analysis of recorded performances, interviews with improvising musicians, and most notably a series of experiments called "micro-scores" – simple exercises in musical interaction – which helped refine and solidify the concepts in the framework.

2.1. i-events

My improvised music analysis framework begins with the presumption that interacting performers, or agents (or agent systems) possess a degree of competence in the production and interpretation of musical signals. Each agent is, at any given moment, in a primary state of either sending or receiving information. This state can be determined by examining the agent's amount of information output, primarily as a function of the rate of change in the agent's sounds.

When musical information is successfully transmitted from one agent to another, a special event occurs. I call such events "i-events" (interaction events). They usually (but not always) manifest as an antecedent/consequent pair of musical signals, each "half" of the event being produced by the sending and receiving agent (or agent system) respectively. Most i-events contain a key, pivotal signal called a cue. An i-event cue is a signal that indicates to the receiving agent that a response has been requested. If the cue is successfully transmitted, the cue-response pair forms a perceived syntactical unit. Such events are of paramount importance in creating the perception that agents are in fact communicating with each other. They are also key markers of the interactive structure of the music.

I-events come in many different "flavors," a few of which are listed below:

- **Imitation**: characterized by a prominent feature of a signal from one agent being extracted and reused by another shortly afterward. This is perhaps the most common type.
- **Question-and-answer**: an i-event in which the response is strongly and clearly consequential to the antecedent cue.
- **Completion/Punctuation**: the first agent provides a cue that is strongly directed toward a predictable "destination" point, which the responding agent meets up with.
- **Interruption**: a signal from the responding agent that tells the sending agent to stop immediately.

The i-event "density" (frequency per unit of time) of a given improvised performance, as well as the "strength" or clarity of these events, provides a quantitative measurement of how much interaction is occurring in the piece. Learning to identify i-events is the first step toward achieving competency in analysis of improvised music. An excellent way to begin working on hearing i-events is to listen to traditional jazz performances, particularly of small groups such as piano trios (piano, bass, and drums). The Bill Evans trio featuring Scott LaFaro on bass and Paul Motian on drums was particularly famous for its highly sophisticated interactions, in which the bass becomes an equal "voice"(Berliner, 1994). In such music, the interactive states of the musicians are particularly clear and the transitions are relatively easy to follow. An analysis of an excerpt of a performance by this group can be seen in video 1 at http://pelz-sherman.net/improv_analysis.

2.2. Fundamental Interaction Modes and their Structural Function in Improvised Music

The framework postulates that improvising performers operate in one of three fundamental "static" modes at any given time during a performance. These modes are sharing, not sharing, and soloing/accompanying. Important features of each mode are listed below:

Sharing:
- commonality of musical materials (rhythm, pitch, timbre, etc.)
- balancing of musical parameters (loudness, note density, etc.)
- shared phrase structure – performers start and end phrases together
- high i-event density

Soloing/accompanying
- one performer clearly has the "spotlight"
- other performers respond to or provide background for the soloist
- medium i-event density

Not Sharing
- independence of musical materials
- independent phrase structure
- low i-event density

The modes can be represented graphically using the notation in figure 1 below. Solid black lines indicate a high relative amount of information output; clear lines indicate relatively low information output.

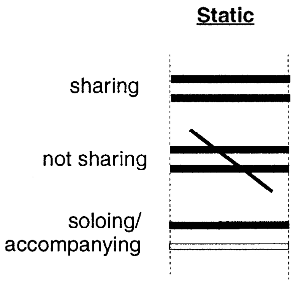

Figure 1: static interaction modes

Fuzzy logic (Kosko, 1993) provides a mathematical model for describing the mode of a given pair of improvisers, as shown in figure 2 below.

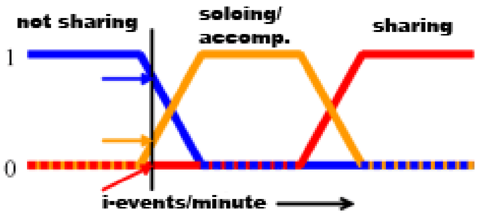

Figure 2: fuzzy logic applied to interaction modes

These 3 fundamental modes are called "static" modes because they describe single, unchanging interaction states that may be observed by looking at a brief "snapshot" of a performance, or by averaging behavior over a longer "analysis window". By observing patterns of transitions between these modes, the framework identifies the following "dynamic" modes:

- **emerging/withdrawing**: from sharing to soloing or not-sharing
- **merging/accepting**: transitioning from soloing or not-sharing to sharing
- **interrupting/disappearing**: one performer abruptly interrupts the other, causing a rapid reversal of states
- **interjecting/supporting**: cyclic mode in which one supporting performer remains in a constant state, while the other constantly changes state, interjecting new statements sporadically
- **initiating/responding**: cyclic mode in which performers exchange information states rapidly, without one or the other becoming dominant

These dynamic modes have two-part names, corresponding to the role of each performer. They are represented graphically as shown in figure 3.

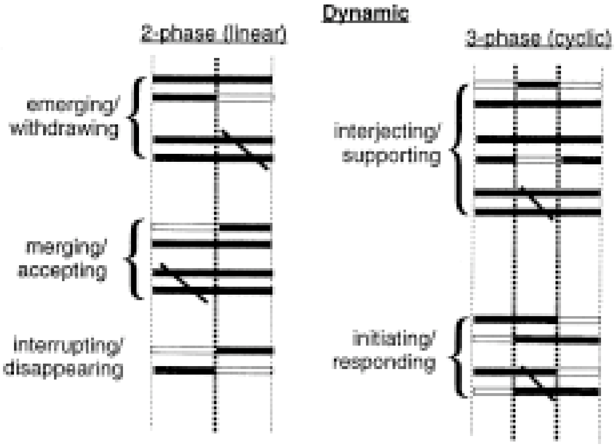

Figure 3: dynamic interaction modes

These modes can be seen in semiotic terms as syntagmatic units of musical signification, which function within a paradigmatic sign system (Perlman and Greenblatt, 1981). The syntactical aspect of a musical interaction – that is, the way events unfold over time – determines its category. However, each mode also has a specific functional or paradigmatic relationship to each of the others. For those familiar with tonal harmonic analysis, it may be helpful to conceive of these relationships by way of analogy to traditional harmonic functions: tonic, dominant, sub-dominant, etc.). Each of these interaction modes generates a different level or type of tension and relaxation, which tend to logically follow one another in a certain order. A suggested mapping of interaction modes to harmonic functions is shown in figure 4 below:

Static Modes	**Static Harmonic Functions**
sharing	= tonic (I)
not sharing	= dominant (V)
soloing/accompanying	= subdominant(IV)
Linear Modes	**Linear Harmonic Functions**
emerging/withdrawing, merging/accepting and interrupting/withdrawing	supertonic, diminished, or secondary dominant (ii7, vii^{o})
Cyclic Modes	**Cyclic Harmonic Functions**
interjecting/supporting, initiating/responding	modal/extended harmony (iii, vi, Dorian, whole tone scales)

Figure 4: mapping of interaction modes to harmonic functions

Three sample analyses of transcribed improvised performances using the concepts presented above can be found at http://pelz-sherman.net/improv_anal.

2.3. Suggested Applications to Sonification Production

A "virtual performer" sonification model may facilitate perception of sonification as interaction. This can be seen as a type of "model-based" sonification (Hermann and Ritter, 1999) where each sonified phenomenon is represented by a computational process that models a human performer. Many examples of such systems have been created by computer musicians: Brad Garton's "style model" pieces (http://www.music.columbia.edu/~brad/music/index.html), George Lewis' "Voyager" system, and Daniel Scheidt's "NORM", to name a few. The essence of the performer model is to extract features from the "score" (or in this case, the data being sonified) and use those features to add expression to the performance. These expressive elements illuminate the musical structure (Sundberg, 1992), allowing the analytical tools presented above to be applied more easily. Using techniques for adding expression to sonifications should help delineate phrase structure and clarify interactive states and transitions. Many techniques exist for this, including structure-based timing deviations, vibrato, portamento, etc. (Pelz-Sherman, 1992).

To maximize clarity, it is important to establish clear correspondences between the phenomena being sonified and the virtual performers and instruments in the sonification. There should be only one instrument per performer, with no switching of instruments throughout the performance. Distinct instrumental timbres and spatialization techniques should be used to aid in channel separation. Employing wide variety of rhythmic values, including rests, is especially important, because discerning interactions among streams is extremely difficult when the rhythm is motoric and constant, as is often the case with sonifications. A performer model may be best suited to intermittent or event-based phenomena rather than continuously changing values. It may be helpful to consider mapping value differences to musical parameters rather than mapping data values directly, so that changes below a certain threshold result in no sound; in this way, rests can be introduced into continuously sampled data.

3. CONCLUSION

The analysis framework presented here is particularly well suited for sonification because it is easy to learn, even for non-musicians, stylistically neutral, and deliberately constructed so as to be amenable to computational, automated methods. The performer-based sonification approach seems especially promising for sonifying complex multi-agent systems in which the listener is either a neutral observer (weather analysis, economic models) or an active, equal participant (distributed virtual environments, network monitoring); specifically, for representing the internal states and interaction modes of intelligent agents in these systems.

4. REFERENCES

[1] Bargar, Robin (1994) "Pattern and Reference in Auditory Display," in *Auditory Display*, Gregory Kramer, ed. Addison-Wesley, pp. 151-165.

[2] Berliner, Paul F. (1994) *Thinking in Jazz: the Infinite Art of Improvisation.* University of Chicago Press.

[3] Borgo, D. (2006). *Sync or Swarm: Improvising Music in a Complex Age.* Continuum Books.

[4] Forte, A. and Gilbert, S. (1982). *Introduction to Schenkerian Analysis.* W. W. Norton & Company.

[5] Hermann, T. and Ritter, H. "Listen to your Data: Model-Based Sonification for Data Analysis." in M. R. Syed, editor, *Advances in intelligent computing and mulimedia systems.* Int. Inst. for Advanced Studies in System Research and Cybernetics, 1999.

[6] Kosko, Bart (1993) *Fuzzy Thinking: The New Science of Fuzzy Logic.* Hyperion.

[7] Kramer, G. (1994). "Some Organizing Principles for Representing Data with Sound," In *Auditory Display*, Gregory Kramer, ed. Addison-Wesley, pp. 185-221.

[8] Nyman, M. (1999). *Experimental Music: Cage and Beyond.* Cambridge University Press.

[9] Pelz-Sherman, M. (1998) A Framework for Performer Interactions in Western Improvised Contemporary Art Music. Ph.D. Disseration, UC San Diego. http://pelz-sherman.net/mpsdiss.pdf

[10] Pelz-Sherman, M. (1992) On the Formalization of Expression in Music Performed by Computers. UCSD M.A. Thesis.

[11] Perlman, A. and Greenblatt, D. (1981) "Miles Davis meets Noam Chomsky: Some Observations on Jazz Improvisation and Language Structure", in Steiner, W., ed. The Sign in Music and Literature, University of Texas Press, pp. 169-184.

[12] Roginska, A., Childs, E. and Johnson, M (2006) "Monitoring Real-Time Data: A Sonification Approach," in *Proceedings of the 12th International Conference on Auditory Display, London,* 2006

[13] Shannon, C. and Weaver, W. (1963). *The Mathematical Theory of Communication.* University of Illinois Press.

[14] Small, C. (1977) *Music, Society, Education*. Wesleyan University Press.

[15] Sundberg, J. (1982) “Perception of Singing”. In Deutsch, D., ed. *The Psychology of Music*, Academic Press.

[16] Vicinanza, D. (2006). *A java framework for data sonification and 3D graphic rendering,* Sound, Music, and Computing.