Broadening Telematic Electroacoustic Music by Affective Rendering and Embodied Real-time Data Sonification

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ABSTRACT

Often played in traditional music performance formats, much recent telematic electroacoustic music focuses on the relationships between people/machines and geographically distributed cultures/spaces/players, and/or it adopts electroacoustic music's historical concerns with natural environmental sound art or space manipulation. But a more suitable environment for telematic art works is perhaps found in the inter-relationship between 'players' and broader contemporary networked life – one embedded in multiple real-time informational data streams. While these streams are often rendered visually, they are also partly interpreted through embodied cognition that can be similar to music and sonic art interpretation. A fruitful meeting point for telematic electroacoustic music and real-time data sonification is in using affective composition/performance and an affective/embodied means of data sonification. To illustrate this, one means of rendering affective telematic electroacoustic music is outlined, and a bridge to one form of real-time data stream representing collective embodiment put forward – forex data rendering – as an example. Amalgamating these approaches in telematic electroacoustic music allows dialectic between networked performers/composers and clusters of collective behaviors. Artistically, this facilitates the notion of how small groups of individuals might plot course(s) of action that are often altered by external pressures, therefore demonstrating a means of exploring participants' placement in contemporary environments.

1. INTRODUCTION

As electroacoustic music studios and traditional concert venues have become more globally connected through high-speed broadband, telematic electroacoustic music practice has rapidly increased. This includes using multiple bi-directional video, audio, and graphics channels, and integrated OSC data control allowing for real-time electroacoustic music composition/performance synchronously within the limits of network latency. A summary of a recent work is given in Fields and Whalley [1].

In mapping a decision space of telematic electroacoustic music from an artistic perspective, Whalley [2] notes that the primary concerns are about the means/methods of production, the nature of relationships between people and people/machines, and the amalgamating of sonic languages when blending diverse traditions within telematic music works.

A limitation of this decision map however, is in not considering an affective dimension of electroacoustic music, or the integration of the medium with real-time data streams that are non-natural based. Yet incorporating these aspects into the decision space allows for a wider consideration of where telematic electroacoustic music might find unique expression.

This paper first outlines some of the generic limitations with current telematic electroacoustic music practice, and proposes as solution to the limitation identified above as one area the field could further explore.

2. TELEMATIC E-A LIMITATIONS

Not surprisingly, many current real-time telematic electroacoustic works replicate what one could do if players/machines were in the same space, but adding remote connection. In developing any new musical practice however, it is inevitable to test 'where it fits' beyond copying older practices to provide legitimacy in the first instance. But what is unique about the telematic medium, beyond the creative use of network latency or conventional electroacoustic music practices, largely remains to be explored in an artistic if not theoretical sense.

2.1 Dislocation of means of rendering and medium

Traditional music performance modes of delivery – making works that are time-bound and requiring linked visual performers to fulfill set performance concert programs for physical audiences at networked linked venues – has determined a good deal of telematic electroacoustic music outcomes. Yet this reflects a small part of the possibilities Follmer [3] sets out in his three-dimensional matrix to show the potential scope of NMP (Networked Music Practice). This includes: Interplay with Network Characteristics – or how the structural characteristics of the network shape the work; Interactivity and Openness – or the extent that users/audiences can join in with and influence outcomes; Complexity and Flexibility – or how musically/sonically flexible the outcome can be. Accordingly, his suggestion is that NMP is best suited to hypermusic (new hybrid instruments), real-virtual/space sound installations, and algorithmic/generative installations.

Hybrid instruments through distributed input and sound object manipulation have received a good deal of attention in practice and the literature as people look to build new instruments suited to this new environment. But a limitation of Follmer's analysis and recent practice is in not widely considering the range of means by which network space can be connected.

In addition, given the flexibility of approaches that can be used in NMP spaces, many current electroacoustic telematic works center on Weinberg's [4] notion of musical structure or composer controlled based goal approaches where participants (agents and/or humans) fill prescribed musical or performance outcomes. This is in contrast to processes-based approaches that explore possibilities or fulfills goals through collaboration or competition and where user experiences may differ with each session.

Given these theoretical schemes, the practice of rendering telematic electroacoustic music into concert hall formats seems somewhat unsuited to exploring much of NMP's wider possibilities, and it may be better rendered as an Internet-focused medium with works played over longer periods, with multiple participants (real and virtual), and with plans that are flexible in real-time. With all performance outputs able to be streamed live to worldwide audiences, Internet-only broadcast may then allow greater exploration of the telematic art medium rather than linked concert hall rendering.

2.2 Relationships theory limitations

In much telematic electroacoustic music practice, relationship models of getting things done from a production perspective are still ground in older practices of composer performer chains of implementation, or Projected Dramaturgy where one node acts as the author and other nodes contribute or project to it, as defined by Rebelo [5]. Less common is his notion of Directed Dramaturgy – where authorship remains with a group or individual who takes on a director's role only; or Distributed Dramaturgy – where authorship is retained by each node while contributing expertise and content to shared production and therefore having more flexible outcomes. A limitation in the scope of this relationship possibilities model here however, is that it does not allow for aggregates of collective behavior that might become useful parts of works through data sonification.

Further, an area that has also received attention in NMP work, given non-trivial machines and how OSC messages can be exchanged between individuals/machines and between groups through Internet2, is the role of intelligent machines implemented through multi-agent technology [6]. As electroacoustic music practice increasingly moves out of edit-based production methods and into live performance, practitioners have two choices at, or between, telematic nodes. These include: a multi-agent system that is self-contained (generative model), or one that can include external input (machine or human) to make a generative improvisational model using intelligent machines. Yet again a limitation of this taxonomy is that machines also need to be considered as something that interacts with external and non-human data streams, rather than just an extension of traditional performance practices, or partners in it, at or between telematics nodes.

While NMP exploration then extends current interactive music paradigms through relationships changes in the roles of composer, musician and producer, anticipates the further deployment of intelligent machines, and more participatory roles for audiences; there are two other areas that are fruitful to address to extend the medium.

2.3 Affective electroacoustic music and data streams

Largely neglected in NMP is the affective/emotive nature of electroacoustic music production, and data stream sonification.

The affective nature of electroacoustic music is not widely engaged with generally in theories of production, yet worth broader consideration [6] as a way of further understanding semiotic function if its communicative nature is to be better understood. Further, while sonification of the natural environment, either by the direct transfer of sound or data sonification in real-time is an increasing part of telematic electroacoustic music practice, real-time sonification of crowd behavior in this context remains to be explored.

Yet what makes networked life unique is not so much that it is inter-connected and high-speed, but what is connected – vast quantities of aggregated data reflecting various types of behavior that is inter-related through single and/or multiple events – and that viewers can be remote yet active responders to these events.

In this networked space, people are embedded in a type of virtual shared collective and interactive limbic system – one also inhabited by ubiquitous intelligent machines that can interact with people and other machines, and one which also monitors and responds to natural environments (weather, seasons, disasters etc.). Furthermore, crowd reactions reflected in data streams like sentiment indicators with their associated feedback loops are likely to be influenced as much by affective concerns (feeling/emotion) as they are by reasoned thinking.

A broader consideration of embedded networked space may then be a better 'natural' space for telematic electroacoustic music practice, reflecting a contemporary aesthetic, particularly if it explores the medium in an affective/embedded way.

3. AFFECTIVE E-A MUSIC

A recent implementation of affective electroacoustic music rendering and representation for telematics electroacoustic music is found in GNMISS (Graphic Networked Music Interactive Scoring System) - Whalley [7]. This allows distributed co-improvisers, mainly using a directed dramaturgy approach in early system tests, to communicate through a scoring system.

GNMISS has four visual layers that illustrate the dramatic structure of works, each represented on a circle with parts for each 'player' to follow. One layer maps emotions to colors based on associated words as a primary basis for gesture and timbre representation. This mapping is based on Plutchik's circumplex scheme of emotions that collates a range of prior studies, and is model often used in affective computing [8] – see figure 1. The limitations of cultural specificity are acknowledged. GNMISS adopts Plutchik's corresponding color attributes for each emotion as a way of representing them efficiently in the score (figure 2).

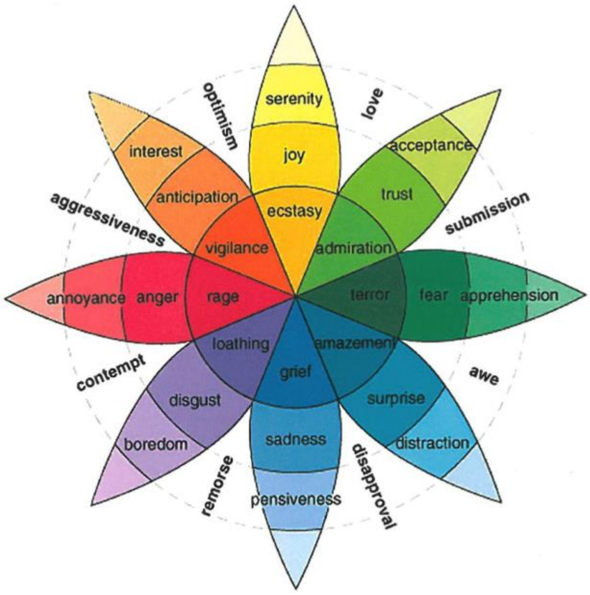

Figure 1. Plutchik's emotion circumplex

A second score layer gives sonic motives and the general frequency range for participants to follow. A third layer allows for more detailed indications of gesture and sound archetypes through representative symbols that were purposed design for the system, to signify types of sound objects to be played during the emotion line by each participant. The inside layer in the circle represents key centers for any spectral information players might adjust to if needed. For timing, the circle turns in clock time with the current playing position always at noon, and a central metronome shows speed independent of clock time.

Technically, client programs sit on distributed machines across the Internet, with data being coordinated by an OSC Server. Any participant or editor can change data in the score from any location and all scores update simultaneously. Distributed scores can then be built by a composer or by a team (players or otherwise). Renditions can have different outcomes depending on participants (people or machines) assembled for the performance, their interpretation of score parts, and interaction with other players' interpretation of their parts.

Central to the sonification of these scores, is the way participants realize their parts in affective ways according to the line ascribed to them. Sonification here then relies on the practical musicianship and real-time control sound makers bring to renditions of the score. The system has been demonstrated in tow recent telematic works *Sensai na Chikai* [9] and *SymbolAct* [10] in 2012.

This approach can also be used to break down the division between audiences and performers, where people take part in the narrative in some sections, but be recipients in another. The circle can be adjusted to any time scale, and parts added within the limits of readability.

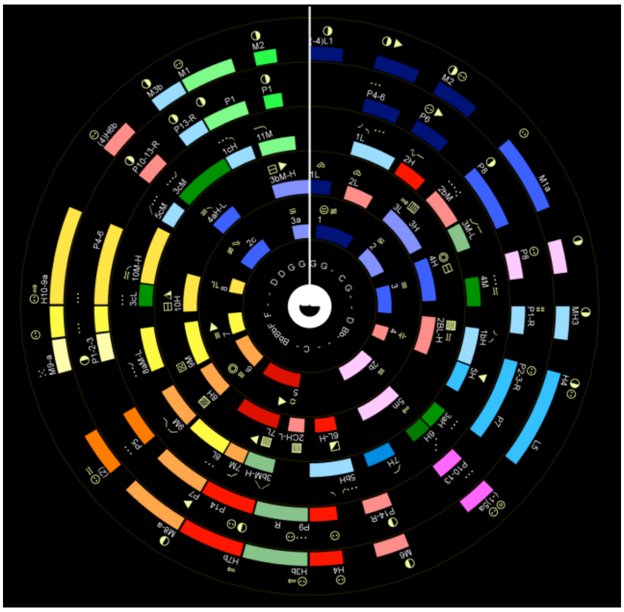

Figure 2. Telematic Score for *Sensai na Chikai*

Through GNMISS, the affective element is brought to the fore and the structure of dramatic works set out, and narratives can be quickly structurally altered as works develop in a collaborative environment by one or more players or non-playing authors.

The use of this system presented the possibility of how external narratives may be included in and influence the interactive affective dialogue of players, and how real-time data-streams of crowd behaviors might be sonified in the context of the GNMISS system to extend its network embedded nature.

4. DATA SONIFICATION

To explore this, a suitable data stream was needed. And one of the best real-time representations of dynamic crowd behavior that is available on the Internet, as well as one responding rapidly to external events (economic, social, natural, political) is foreign exchange trading data (forex). Further, as one of the world's largest financial markets, it directly influences many of our lives. But it is also useful from a NMP perspective because it provides rapid action in small time frames, reflecting a range of human actions and machine based algorithmic trading – a meeting point between machine and human rapid decision-making.

4.1 Sonification: Suitable Approaches/Frameworks

Aspects of the recent scope of data sonification are well covered in recent literature such as *The Sonification Handbook* [11], the International Conference for Auditory Display (ICAD), and a recent edition of *Organised Sound* [12].

Vickers and Hogg [13] provide an overview of the aesthetic issues in the field: particularly the relationships between sonification (ars informatica) and music and sound art (ars musica); and abstract in contrast to concrete approaches to sonification. They represent this on a circular diagram to show the continuity between different approaches.

From their schema, a suitable solution needed to sonify a forex data stream for the purpose of incorporating it with GNMISS pointed to an ars informatica approach, but one that leaned toward the metaphorical mapping of data – particular because the intention was to include some sort of embodied sense of the data stream.

More broadly, the sonification of financial data has received ongoing attention in the literature. Worrall [14], for example, gives a summary of approaches to sonifying capital market data, and the difficulties of doing this in terms of direct mapping, noting that the markets do not resonate according to acoustic laws. His solution proposed was transforming the data so that it resonates, but this approach is not well suited to the metaphorical translation needed to address extending GNMISS.

4.2 Embodiment

In line with requirements set out at the beginning of the paper, Grossman [15] puts forward a productive starting point regarding sonification used for knowledge generation as an extension of auditory sensibility toward previously imperceptible properties of our environment. Accordingly and based on the nature of our bodies that are mediators between a shared exterior individual interior world, he suggests a model that covers three problematic areas of bodily extension: the cognitive, the physical and the extended. The value of what is proposed here, is that it makes thinking in embodied terms central to sonification, and the notion of both individual and group embodiment of data, and the relationship between these two.

4.3 Mapping

The need for subtle mapping that will make sense in an embodied way to audiences is also a continuing concern in the literature. Worrall [16], for example, puts forward a method called a Gesture-Encoded Sound Model (GESM) toward synthesizer parameters being mapped to data in a way that makes sense to general listeners, influenced by performing musician input to aid this mapping.

Extending this, Worrall [17] again notes the need to understand micro-gestural inflections in the parameter mapping of sonifications, arguing that many computer music software tools used for data sonification are unsuited to the task due to being based on adaptions of computer music tools suited to playing notated scores.

But, as recent research suggests, listening is embodied and invisibly enacts internal gestures accordingly, so sonification using parametric mapping should incorporate micro-gestural inflections to enhance the intelligibility of aural translation from the data.

From the perspective of extending the NMP perspective, the notion put forward of getting musicians involved in the potential mapping problem early as part of the solution was worthwhile.

4.4 Affective mapping – prior literature

Two recent articles have looked at the affective mapping of in terms of capital markets, and data sonification generally in electroacoustic music.

Kirke and Miranda [18] in *Application of Pulsed Melodic Affective Processing to Stock Market Algorithmic Trading and Analysis*, put forward a system that utilizes 'melodies' representing affective states, noting that affective computing is an increasing part of recent artificial intelligence development, and such work is also in line with the progress of HCI looking at the understandability of affective outputs to users/engineers. Their PMAP method then facilitates an understanding of an affective processing path by both hearing an aspect of affective computing process and interfacing with simple affective input/output systems. PMAP, in the example given, is applied to an algorithmic trading system interacting with an affective-based model of a simulated stock market. The leap made here is in connecting affective computing with metaphorical data representation (mood) in real-time, although using a simpler map of emotions than that adopted by GNMISS. But for the purposes of extending GNMISS, the limitation of the work is in not embedding the sonic output in performer-based embodiment, and in the limited range of sonic representations of affective outputs in comparison to Plutchik's emotion schema.

Finally, a recently released paper providing a systematic way of evaluating the relationship between sonification and emotional representation is Wanderley and Winter's [19] *Sonification of Emotion: Strategies and results from the intersection with music* – again in line with affective computing developments. After identifying favorable contexts for the auditory display of emotion and surveying the state of the research field, they reinforce the conditions needed for sound to meet the requirements of sonified emotions. Accordingly, strategies for display are given that use acoustic and structural cues intended to trigger selected auditory-cognitive mechanisms of musical emotion. In applying the outcome to sonification to convey a selected range of emotions – using one approach designed ecologically and another computationally and evaluating the outcome – they illustrate that while a computation design performs better, an ecological design is better suited to emotional communication. They then point to development of computational design/evaluation for future development.

This seminal work provides a means of more accurately linking sonic production to intended emotional response in artistic work that had largely been widely articulated intuitively by musicians using GNMISS. And the ongoing work may provide a more systematic basis for translating aspects of real-time data streams aurally in ways that will make emotional sense to wider audiences.

5. THE DATA STREAM SONIFICATION

5.1 Framework

For the purposes of the test to extend the GNMISS system, the USD/JPY real-time forex exchange rate was used – mainly because it is a stream that is very active in the Asia/Pacific region during working/evening hours, so provided significant price and volume action during the testing periods. This forex stream was set to one-minute intervals for display.

Using basic technical indicators for forex trading (figure 3), the candles give the strength of sellers (red) or buyers (blue) in the market. The size of the candle body gives the opening and closing price of the currency bought/sold within each minute, and the wicks of the candles indicate the high and low points of the price within each minute time frame. The blue boxes at the bottom represent accumulated tick volume per minute. Apart from the diagram information, the changing tick value within each minute is available numerically in fractional pips.

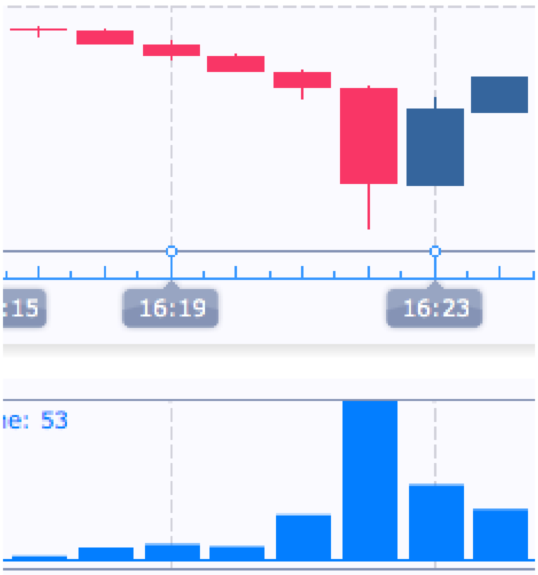

Figure 3. Candlestick rendition of sellers and buyers, and proxy of volume in tick data at the bottom, over an eight minute period.

A tick is a change in the value of an exchange rate, or the outcome of buyer/seller action. Volume in these terms is the number of times within the minute that the exchange rate changes in value. A pip is a fraction of a currency. A pip for dollar-based currencies is 1/10,000th of a dollar (i.e. the fourth decimal place). A pip for yen-based currencies is 1/100th of a yen (i.e. the second decimal place). But some currency exchange dealers operate in 1/10th of pips, or fractional pips where the exchange rate is quoted to either 5 or 3 decimal places – dollars and Yen respectively – which was the case for the Yen data stream used in this project.

The questions were then how to sonify the trend to make sense of the direction of trading, how to sonify data movement within the current minute, and how to make the sonic output somewhat distinct from the affective output in GNMISS so that it could be heard and remembered in the context of GNMISS performance.

To begin with, only the prior five minutes of trading data was used to identify a market trend, because this gave an adequate time scale to provide the market direction suited to performances in GNMISS. The tempo of the GNMISS score rotation and the market data stream changes were both 60 bmp so that they synchronised with each other.

Based on the literature put forward, to get an embodied sense of how the forex stream might be communicated in a meaningful way to musically adept people who may take part in GNMISS based performances, as well as communicate with audiences, three adept musicians and sound object manipulators using their 'instrument' of choice were given five common forex trends in the USD/JPY to realise sonically, as well as the current data stream movement represented in a moving tick line to respond to. Player slowness of response to real-time tick value and lack of exact accuracy in sonically interpreting trends was accepted in favour of getting a sense of sonically embodied solution in the first instance.

Their recordings were played back to a second set of three players who were given the visual data streams diagrams they were rendered from, but they were not told which audio file belonged to which visual representation, to see how closely they could match the sound files with visual renditions. Interestingly as test progressed, the listeners became better at physically drawing closer approximations of the sonic outputs in candlestick and volume bars, without referring to the corresponding charts.

Over four weeks this informal method resulted in finer iterations of sonic renditions, based on production and feedback between performers and blind testers. From this work, a set of basic rules was devised to sonify the data in a way that made sense to both groups. The performances made, however, only provided approximations of more accurate outcomes that might be possible by mapping parameters directly in to sound from the data stream, once rules were known.

From mapping largely macro gestures through performance, a simple range of possible sound parameters that might be mapped directly from the data stream was considered, such as tempo, rhythm, volume, timbre (multiple parameters), ADSR, pan, and effects such as distortion, delay, filter, filter delay, phase/flange, spectral manipulation, reverberation/ echo, granular manipulation. Based on the performance test made, the best sonic translations identified came down to only a few useful elements (see next section). Partly this may have been because two GNMISS players used in some of the forex sonic translation trials were also aware of the need for the forex stream sonification to be distinctly identified in GNMISS performances.

The most complex part of parameter mapping was the selection of timbres by performers to interpret various aspects of the stream. Accordingly, where there was most agreement on what was suitable as representation, timbres to be mapped were kept as close as possible to the dynamic 'patches'/sounds that performers selected, to retain their communicative sense.

While more subtle micro-gestural elements were also captured as part of performance trials, these were set apart in the first instance in favor of encapsulating broad gestures for the purpose of first integration tests between the sonified stream and GNMISS.

5.2 Basic mapping

Accordingly, the first version of a sonic macro rule set was mapped as follows, bearing in mind that the stream had to be represented as a trend, a current state, and be recalled in the process of a GNMISS performance.

Starting point. The first pitch of any piece (i.e. corresponding to the opening value of t-5) is always A440; thereafter, every fractional pip change in exchange rate is equal to a 1/3 semitone change in pitch. It is accepted here that if one used this sonic output to trade forex fractional pips, it would be a somewhat crude representation of accuracy.

Previous 5 Summary. Scope: Pitches in microtones corresponding to data information (open value, close, high and low) for each of the five minutes prior to the current data stream. The performance order of the pitches is open, extreme 1, extreme 2, close: depending on the overall direction (up-down) for that minute. e.g. a blue candlestick (overall direction = up) goes open, low, high, close. The *Previous 5 Summary* plays before the data stream commences (i.e. 20 seconds before t=1), and then concurrently with the data stream at the beginning of every minute. Rhythm: Each pitch lasts 0.5 seconds; 1 second space between one closing value pitch and the subsequent opening value pitch. Finally, open and close (t-1) are sustained for two seconds after the close of the value to help players locate the current tick stream. Pan: Open value always on the left, close value always on the right, high and low value in the middle. Volume: corresponds to the tick volume of each previous minute, relative to the tick volume of t-5; every 10 points extra in tick volume per minute corresponds to 0.5dB increase for that minute, beginning at 0dB. e.g t-5 tick volume = 50 (Vol. = 0.0dB); t-4 t.v. = 100 (Vol. = 2.5dB); t-3 t.v. = 30 (Vol. = -1.5db), etc. Timbre: Opening and closing values played legato in warm tones; high and low value played staccato in warm tones.

Trend Summary. Scope: 5 consecutive pitches for the previous five minutes; pitches correspond to the Simple Moving Average Value, using 'Weighted' as the data source and '1' for the number of periods. *Trend Summary* is first heard directly after the closing value of t-1 at the beginning of the work. Rhythm: Each pitch lasts for 0.2 seconds. Volume: this remains constant. Timbre: Bright/warm/percussive.

Trend Summary II. This is a mnemonic for the overall trend. A combination of the Trend Summary pitches, followed by the open and close value pitches from the most recently completed minute. The *Trend Summary II* is heard at 20 seconds and 40 seconds within each minute. Rhythm: The Trend Summary pitches last, cumulatively, one second; the open and close value pitches also last one second. Pan: Centre for the Trend Summary pitches; pan left for the open value; pan right for the close value. Volume: Constant. Timbre: Trend Summary timbre plus warm tone, with the warm tone parts having a slow attack and decay plus a fade.

Current Data Stream: Pitches corresponding to the value of the exchange rate as it moves in real time in microtones. Rhythm: Dependent on tick speed. Pan: Constant from left to right as the minute unfolds. Volume: Constant. Timbre: Sine wave tone with the note length/attack/decay dependent on the relative distance between ticks; every fractional pip in distance (i.e. 0.001 Yen) is equal to a note length of 100ms, with the same envelope shape applied to attack/decay functions. For example, a constant trend will have same value note lengths; and a trend with an increasing rate has note lengths that lengthen so that jumps in tick distances will be more pronounced.

5.3 Implementation

Once these macro rules were extracted, the forex data stream output was captured and programed in MAX/MSP to the sonic parameters outlined in the rules given above based on the performer/listener tests. This direct mapping allowed a faster response to the real-time tick stream and more accurate mapping response than performers could approximate in real-time following trend values.

This first version of the rules only dealt with the data in broad performance gestures. Current work beyond this is looking at the mapping of micro-gestural information captured from performer interpretations using the WEKA machine-learning suite at Waikato University, to develop more subtle performance representations of a wider range of sonic parameters. Some initial testing of this uses the same performers and blind evaluation method used in arriving at existing rule set outlined in section 5.1. Not surprisingly, and in line with Worrall's work, it is generally worth noting that performance value in traditional and live electroacoustic media, such as real-time articulation, vibrato, envelope control, and timbral manipulation, are often what engages with audiences beyond raw pitch/duration/tempo based data.

6. INTEGRATION

Again, by using five minutes of the data stream, one could represent the trend of the market within a timeframe that suited the timescale of affective rendering used in GNMISS. Secondly, one could put most of the sonification detail into the movement of the current minute, driven by the rapidly changing tick data and the directional movement of the market in terms of buyer /seller influence, where the greatest influence on GNMISS participants was needed.

A visual rendition of the data stream – the last five candle sticks and the tick volume – was then placed at the top left-hand corner of the of the GNMISS scoring system, with colors mapped only in black and white to save confusion with the circular score affective system, so that players could see the overall trend overall of the market at any time in addition to its sonification. The current minute, representing changing ticks and candlestick direction, was placed at the top right of the GNMISS scoring system. Participants could then follow the dramatic nature of their GNMISS score part in an affective sense, but all could also see/hear the movement of the forex stream in terms of the visual and sonified current minute in the context of the trend.

The data stream, and its impact depending on the strength of the trend and current movement, could then influence participants. If little happed in the data stream, it could be largely ignored and the general course of action set out in the GNMISS score pursued by participants. But the external influence would increase with the directional shape of the trend and movement in current data. With large movements in external data, participants may then also stray from their own score parts, and even attempt to follow aspects of the sonifed data stream, overriding the own path on the GNMISS score.

From an artistic perspective then, this approach provides a means of embedding performers in an affective scheme where they make plans in a structured narrative to which they contribute planning for, but the actions of individual and groups can be altered by short term and larger external forces that disrupt and change plans. Further, one cannot anticipate what is likely to happen, because the structure of the real-time external data is not known in advance.

7. CONCLUSIONS

The paper began by outlining some of the limitations of current telematic electroacoustic music practice. A suggested way forward was to extend it into the interconnected webs of influence that are unique to net space beyond current NMP practices, but also taking into account individual placement within these webs. The solution proposed to address this is an embodied and affective meeting point between the two. It amalgamates the affectively based GNMISS system with an embodied sonic interpretation of a forex stream based in player musicianship, as one example of the concept.

In addition and from a structural sense, the approach suggested here opens the possibility of exploring more flexible approaches to telematic music focused on process-based methods, where multiple authors discover possibilities or fulfill goals through collaboration or competition, but are influenced by changing external real-time data streams that may impact on sessions as they progress.

With contemporary life being increasingly mediated by multiple data streams, relationships between people and the Internet of aggregated information is fruitful ground for further electroacoustic music telematic exploration.

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