FLOOD TIDE SEE FURTHER: SONIFICATION AS MUSICAL PERFORMANCE

Dr. John Eacott
School of Media Arts and Design
University of Westminster
London
UK
john@informal.org

ABSTRACT

This paper addresses the practice of creating musical performances from environmental data. There is particular reference to the authors’ works Flood Tide and Hour Angle and the ideas and principles behind these are outlined with an explanation for the surge in interest in sonification as a means of creative expression. The main part of the paper explains the thinking and algorithms used specifically for the event Flood Tide See Further. A section is also devoted to the ways compositions generated in real time can be converted into notation that may be performed with live musicians.

1. INTRODUCTION

In recent years there has been increasing interest in sonification as a means of artistic expression or music [1]. Practitioners are finding ways of connecting a wide range of data sources to sound or music output leading to vastly different results. Pieces or organisations that have come to my attention include:

- Robberto Mannai’s CodeSounding converting computer code into music [2].
- Tom Dukich’s Pi to 500 Decimal Places: Piano solo [3].
- The Locus Sonus group of sonification artists [4].

Since 2008 Informal [5] have been creating musical performances by mapping slowly changing environmental data to musical parameters. The musical output has focussed on two related sonification works Flood Tide and Hour Angle. Both works sonify gradually changing environmental data by mapping data values to musical notation performed in real time by musicians.

This paper documents some of the ideas and practice behind these works and considers in particular one of the more recent and largest events to date, Flood Tide See Further, in which an entire incoming tide lasting 6 hours was sonified with an ensemble of 39 musicians. Sonification may be loosely defined as the representation of data using non speech sound [6] although wider interpretations are emerging as defined by the Locus Sonus group and others. This paper has five parts. Following this introduction section two introduces the works Flood Tide and Hour Angle, section three considers some reasons these works exist with an argument for making music by sonifying environmental data. Section four looks at Flood Tide See Further in detail and explains some of the processes used. Section five looks at our use of live generated scores we call LiveNotation, its importance in this work and how it is being developed.

2. THE WORKS

Flood Tide and Hour Angle are a pair of related sonification works. They both sonify slowly changing environmental data. Flood Tide uses live readings of tidal water flow using a physical sensor and Hour Angle calculates the angular relationship between the Sun and Earth. Both works employ similar processes to convert the data into musical parameters which are converted into notation using our own LiveNotation software. The notation is read by a group of musicians resulting in a live musical performance.

2.1. Flood Tide

Flood Tide sonifies tidal flow. The setup for a performance includes a physical sensor to read the speed of tidal water. The data from this sensor is sampled every 5 seconds to provide a value from which musical material is generated. The initial concept of the piece was to make live music from an entire incoming (flood) tide which in many locations takes approximately 6 hours. One reason for choosing tide as a source of data is that it has a natural and predictable structure. Readings of tidal flow in the Thames at the Southbank for example follow a roughly sinusoidal path over a period of 12 hours in which the flood portion can be represented as the positive part. This part, beginning at zero, building to a maximum value after 3 hours and returning to zero at 6 hours forms the structure of the music.

There have been 10 performances of Flood Tide to date:

- Flood Tide 1&2 Trinity Buoy Wharf. 28th & 29th June 2008 (100 mins - 2 x celli, marimba, vibraphone. Audience ca. 70 + 70)
- Flood Tide 3&4 Trinity Buoy Wharf. 20th & 21st September 2008 (2 hours - 2 x celli, marimba, vibraphone. Audience ca. 70 + 70)
- Flood Tide 5&6 Stratford Upon Avon River Festival. 4th & 5th July 2009 (2 hours - 2 x celli, alto flute, bass
clarinet, marimba, vibraphone. Audience ca. 100 + 150
• Flood Tide 7&8 Royal Observatory Greenwich 25th and 26th July 2009 (2 hours – sextet. Audience ca. 200 + 100)
• Flood Tide 10 See Further, Southbank, London. 4th July 2010 (6 hours. Ensemble of 39 orchestral musicians, voices, taiko drummers and jazz soloists. Audience ca. 1000).

2.2. Hour Angle

Hour Angle sonifies the gradually changing angles between earth and sun. In particular the four previous Hour Angle performances have all been based on the sun’s declination or north / south component which varies gradually over one year. Like tide, declination also follows a sinusoidal path between approximately 23.7 degrees north at the summer solstice and 23.7 degrees south at the winter solstice and crossing zero declination as the sun crosses the equator at the spring and autumn equinoxes. Declination is generally calculated using data published in a nautical almanac [7] for the purpose of astro-navigation at sea. For some performances however, I have used a mathematical sine function based on the known maxima / minima points (solstice / equinox) on the astronomical calendar which results in similar data although not quite as accurate as the nautical almanac data.

Hour Angle performances have been as follows:

• Hour Angle 1, Summer Solstice. (30 mins, 2328 20th June 2008 Pullens Festival, Kennington, London. (2 x Celli, Marimba, Vibraphone. Audience ca. 60)
• Hour Angle 2, Spring Equinox, (30 mins, March 21st 2009 Rose Bruford College, (Trumpet, 2 electric guitars, electric bass, keyboard and percussion. Audience ca. 60).
• Hour Angle 4 - Artesian 7pm 29th Nov 2010, The Horse Hospital Bloomsbury. (20 mins, Soprano, Tenor, Horn, Trombone, Marimba and Keyboard. Audience ca. 40).

3. WHY SONIFY DATA AS MUSIC?

Although interest in sonification as music has increased there is a fundamental issue or even paradox about its purpose. If the purpose of a sonification is to represent data there are simpler, clearer and cheaper ways to do it than using, in our case, live musicians. To put it another way, these sonification pieces are built on an assumption that there is a value in representing data as music rather than sound.

Furthermore, the representation of data and the creation or music are very different acts and it is not easy to see why or how they can be combined satisfactorily. It could be argued that neither Flood Tide nor Hour Angle are effective at either. i.e. they don’t represent the data clearly and they don’t necessarily make good music!

There is an argument for musical sonification however. Following the performance of Flood Tide See Further a panel convened to discuss sonification from an audience perspective. One of the questions considered was whether the audience learned anything about the data being sonified. The overwhelming reaction from this panel was that in the case of Flood Tide it caused people to think about the tide cycle. It is remarkable perhaps to note that many Londoners attending Flood Tide knew little about tide and that it goes in and out approximately every 12 hours for instance. Although the precise details of that particular tide, despite being displayed (and sonified) to 2 decimal places is not particularly relevant to the average Londoner the overall idea, to make music from that data is. Audiences will stop and listen to a musical sonification, even if the music isn’t that good, because it is music. As a result it may be argued that the fact an audience has engaged with the sonification and experienced and considered the data being processed exposes the data to audiences that would not otherwise encounter it.

Another reason to make music by sonifying data is simply because we can. Sonification is a further example of an art form that has been opened up by advances in computer technology. It is a means of contemporary cultural expression.

4. ALGORITHMIC PROCESSES

Our use of sonification is as a form of artistic expression and musical composition. In other words we take data and convert it into - or present it as - music. The music is generated from a combination of 5 mappings of the received data into musical parameters, tempo, rhythm, pitch, playing instruction and orchestration.

4.1. Tempo

In Flood Tide the mapping of musical tempo (speed of the music) is an almost direct translation of the data
received from the sensor. So when the water is slow the
music is slow and when the water speeds up so does
the music. A constant multiplier is chosen that maps
the expected range of tide rate to limits of musical
tempi that are playable by humans and, in our view
lead to a musically acceptable result. At Flood Tide
See further the expected range of tide rate at the sensor
mounted on Festival Pier was between 0 and 2 knots.
From experience of previous performances and
considering the mixed abilities of the musicians I
wanted the tempo to not significantly exceed 120 bpm
(beats per minute). A simple mapping of :
tempo = tide rate \times 60 \text{ was appropriate}.
The qualification ‘almost direct’ is used because of
issues that, if not addressed, would cause the
performance to break down. In the case of the tempo
mapping a zero value results in no music. However, it
is necessary for the musical tempo to remain greater
than zero. This is because new musical data is
generated at the end of each musical bar and if the
musical tempo were allowed to reach zero the musical
data would never get updated. So in order to keep the
musical tempo moving but largely retaining the clarity
of the tempo mapping the equation becomes:
tempo = (tide rate \times 60) + 2
So even when the tide rate value is 0 the tempo never
drops below 2 beats per minute.

4.2. Rhythm and meter

The second mapping is rhythm and meter. The rhythm
element is achieved with a simple process where I
convert the tide rate reading firstly to an integer (by
multiplying by 100 say) and converting the integer as a
12 bit binary number. For example
tiderate = 1.87 \times 100 \text{ and converted to integer) = 187.}
Then converted to a 12 bit binary number
187.asBinary

[ 0, 0, 0, 0, 1, 0, 1, 1, 0, 1, 1, 1 ]

This array is then treated as a musical rhythm in which
the 0s represent rests and the 1s represent notes.

This conversion may appear rather arbitrary but is a
method that we have used in all Flood Tide and Hour
Angle performances because it generates, arguably, a
satisfying musical progression. Although a single
value may look like a rather random rhythm, as the
tiderate values gradually change it is possible to hear
the rhythm permeate gradually and logically. In one
sense the rhythm is simply a representation of the data
value but in a musical sense it shows progression.
For Flood Tide See Further (2010) variation of meter
was introduced. Until this performance all previous
Flood Tides had been limited to 12 beats in every bar.
Meter variation was a simple scheme based on elapsed
duration only and not dependent on tide rate. Meter
would vary between 5 and 12 beats per bar with 5
chosen as lowest value because with smaller values the
musicians would have too little ‘look ahead’ time to
read the music satisfactorily. 12 remained a maximum
because of concern that with larger values the music
becomes hard to read rhythmically.
The scheme simply started at 5 beats per bar and incremented, adding a beat every 3 minutes. So each
meter of 5, 6, 7, 8, 9, 10, 11, 12 (8 different meters)
was used for 3 minutes and then it started from 5 again.
A whole cycle of meter variation lasted 24 minutes (8 x
3 minutes).

4.3. Pitch

The pitch scheme for Flood Tide is also simple. The
scheme uses a predetermined cell of three notes,
typically C, D and G. This cell, lets call it cell1, has an
identical twin cell2. At a zero or very low tide rate
cell1 and cell2 are identical but as the tide rate
increases the root of cell2 is transposed up a semitone
(from C to C♯) to produce a pitch set of 6 notes [C,
C♯, D, D♯, G, G♯]. As the tide rate passes a further
threshold cell2 is transposed up a further semitone
which creates a different pitch set, this time of only 5
notes as the note D is duplicated [C, D (D), E, G,
A]. Twelve thresholds are predetermined that aim to let the
pitch scheme explore all combinations of cell1 and

cell2.

Several considerations have led to this pitch scheme.
One overall consideration is about the general range
and type of tonality the piece should have. Flood Tide
was conceived as a work for a potential wide audience.
With this in mind, and without making crass
assumptions about the abilities of a general audience to
enjoy complex or atonal work, the piece is designed to
be largely tonal, but with aspects of tonal tension and
polytonality.

This pitch scheme is also very simple and sidesteps the
need for constructing any form of ‘classical’ harmony,
i.e. there is no notion of triads or chords as such. This
implementation of pitch set harmony has a rather
limited range of possibilities. Excluding pitch sets that
are transpositions of a previous one (i.e. a set made
from roots C and E is a transposition of a set made
from C and A♭) there are only 7 distinct pitch sets
which are when cell2 has the roots (C, C♯, D, D♯, E,
F, F♯).

We can number the full range of pitch sets (including
transpositions) set 1 to set 12 and characterise them as
follows: (The notes within each set are octave
transposed to remain within one octave i.e. from C up
to B). The root of cell 2 is in parenthesis and the pitch
set in square brackets.

1. (C) [C, D, G] (open 2nd 5th)
2. (C♯) [C, C♯, D, D♯, G, G♯] (cluster / poly
tonal)
3. (D) [C, D, E, G, A] (C pentatonic)
4. (E♭) [C, D, E♭, F, G, B♭] (C minor 11th chord)
5. (E) [C, D, E, F♯, G, B] (C major 7th #11 chord)
6. (F) [C, D, F, G], (open 2nd, 4th, 5th)
7. (F♯) [C, C♯, D, F♯, G, G♯] (cluster / poly
tonal (- more dense than set 2))
8. (G) [C, D, G, A] (transposition of 6)
9. (A♭) [C, D, E♭, G, A♭, B♭] (transposition of set 5)
10. (A) [C, D, E, G, A, B] (transposition of set 4)
11. (B♭) [C, D, F, G, B♭] (transposition of set 3)
12. (B) [C, C♯, D, F♯, G, B] (transposition of set 2)

4.4. Playing instruction

As well as tempo, rhythm and pitch variation it is desirable, particularly in a piece of long duration, to have variation of instrument timbre, playing technique and for the vocalists a change of text. In Flood Tide this is achieved with a pre-determined set of playing instructions for each instrument which the instrument part cycles through, one after another. Playing instructions are chosen for groups of similar instruments i.e. strings, woodwind, brass, voices, tuned percussion, taiko drums. In the case of strings for example the techniques were [legato, sustained, pizzicato, legato tr, sustain tr, pizz tr]. Some instructions are weighted, i.e. they occur more or less often and these weightings are selected to achieve a musical balance. Or put another way, instructions for special effects that bring additional timbre but become annoying if over-used like trills occur less often. Text for the vocalists was chosen from a chapter about tide from a manual of sea navigation [8].

4.5. Orchestration

For Flood Tide Thames Festival (31 musicians over 2 hours) and Flood Tide See Further (39 musicians over 6 hours) a scheme was developed to vary which instruments a playing at a given time. This scheme has two purposes: to manage the endurance of musicians and allow them to rest, and to introduce timbral and dynamic variation to the music by making different combinations of instruments. In Flood Tide See Further the expected 6 hours of performance was divided into 18 sectors of 20 minutes (numbered sectors 1 to 18). The ensemble was broken into 16 instrumental groups - this number having the practical limitation as the maximum number of individual parts that could be displayed using the chosen hardware system (see below).

Each sector featured a unique combination of the 16 instrumental groups. The choice of groups reflected the overall dynamic shape i.e. starting very quietly, building to a maximum dynamic at 3 hours then decaying to silence again at 6 hours. Although the music is driven by the speed of tide, the height of tide is also reflected by an overall rise in pitch throughout. So the piece began with pianissimo double bass joined by bass trombone and bass voice. Instrumental groups join until a ‘tutti’ during the central hour and then groups depart leaving flute, soprano voice and solo violin in the closing stages.

4.6. Melody, harmony, thematic continuity and development

As described above, pitch is governed by a scheme of 12 pitch sets. Musical qualities such as melody, harmony, counterpoint, thematic continuity and variation are not designed or programmed specifically but occur from the processes, and more importantly perhaps, the interaction of processes described above.

4.6.1. Melody

To give an example, a melodic line is the product of the pitch set in use and the rhythm in use. In other words, the rhythm chooses which notes of the pitch set that are played. Although the pitch set may remain static for up to an hour the rhythm (derived from tide rate changes sensitive to on hundredth of a knot) changes more frequently.

4.6.2. Harmony

Similarly, there is no specific scheme to determine harmony but it occurs from the unfolding of existing rules. In essence Flood Tide can be thought of as a unison phrase unfolding over 6 hours. Because of variations of interpretation of the unison, particularly the use of sustains in which the musician holds the given note until the next note appears (or until their breath runs out) a harmony emerges. This technique of building harmony from extending melody occurs in various ways in many kinds of music, rounds, cannon etc. I became interested in the technique while studying Boulez ‘Pli Selon Pli’ as an undergraduate. ‘A’ by John Harborne for the jazz group Loose Tubes also employed the idea.

4.6.3. Generating instrumental parts

The ensemble of 39 musicians in Flood Tide See Further is divided into 16 instruments. Each instrument has a unique part that the musicians read from a computer screen. Some instrument parts are played by several musicians as is normal in an orchestra i.e. Violin 1 for example is played by 5 musicians (denoted with a number in brackets).

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Musicians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Violin 1 (5)</td>
<td></td>
</tr>
<tr>
<td>Violin 2 (4)</td>
<td></td>
</tr>
<tr>
<td>Viola (2)</td>
<td></td>
</tr>
<tr>
<td>Cello (2)</td>
<td></td>
</tr>
<tr>
<td>Double Bass</td>
<td></td>
</tr>
<tr>
<td>Flute</td>
<td></td>
</tr>
<tr>
<td>Bass Clarinet</td>
<td></td>
</tr>
<tr>
<td>Trumpet</td>
<td></td>
</tr>
<tr>
<td>Horn</td>
<td></td>
</tr>
<tr>
<td>Bass / Tenor Trombone</td>
<td></td>
</tr>
<tr>
<td>Marimba</td>
<td></td>
</tr>
<tr>
<td>Vibraphone</td>
<td></td>
</tr>
<tr>
<td>Voice Soprano (2)</td>
<td></td>
</tr>
<tr>
<td>Voice Baritone (2)</td>
<td></td>
</tr>
<tr>
<td>Taiko Drums (2)</td>
<td></td>
</tr>
<tr>
<td>Jazz Soloist (3 - tenor sax, trumpet, drums)</td>
<td></td>
</tr>
</tbody>
</table>

Although all instrumental parts are generated from the same set of rules a unique part for each of the 16
instruments is generated by including small systematic variations to some of the rules. Often these variations are the inclusion of a unique instrument parameter constant. Taking rhythm as an example a constant, unique for each of the 16 instrument parts is applied in the conversion from tide data to rhythm array. This results in instruments having nearly similar, or complementary rhythm parts. Similar instrument parameter constants are used for the generation of playing instructions while other rules such as pitch and meter are applied universally across all instruments.

4.6.4. Thematic continuity and development

In a work of this duration (6 hours) driven by simple compositional algorithms thematic continuity is perhaps too easy to achieve and there is a danger of excessive repetition. Designing a system that generates sufficient development and variation to sustain the listener but also produces music that is coherent and interesting is a significant challenge.

The approach taken here is to combine several processes to generate musical information. Each process is simple but together they are designed to complement each other and the overall composition emerges as a result of the combination and interaction of these processes. Most processes are driven by live tide data but there are some processes, like the rule for varying meter (above) that are pre-determined. Additionally the rules for which a unique instrument parameter constant is applied is marked with an asterisk (*).

- Tempo (tide data)
- Meter (pre-determined)
- *Rhythm (tide data)
- *Pitch (tide data)
- *Timbre (tide data)
- *Orchestration (pre-determined)

It is hoped that because each instrumental part is unique but related to every other part the combination of parts is to some extent both interesting and coherent.

5. LIVE NOTATION

At the heart of Flood Tide is a method for representing the music generated on computer screen so that it can be performed by the musicians. Despite the rapid advances in many areas of digital music technologies, the facility to represent musical data generated in real time is not widely available.

5.1. Background to live notation

There are several individuals or companies that are pioneering real-time generation of music notation. These include MaxScore [9], a plugin for Max/MSP and a facility for score generation in Nick Didkovsky’s Java Music Specification Language (JMSL) [10]. There have also been attempts to generate notation live using Lilypond. and an ambitious project - eScore - by Christopher McLelland and Michael Alcorn to create a tool for composers to generate notation during a performance [11]is in development.

The key differences between a system for live notation and conventional notation are:

- The need to show a metronome or cursor to keep musicians in sync
- there must be a way of continually scrolling the music so that musicians can look ahead
- the notation must be easy to sight read

A brief look at available real-time score generating systems suggests that although representing music notation on a computer screen may appear to be a relatively trivial task there are good reasons this has been slow to develop. Considering the ergonomics of the design and the necessary compromises in terms of the sophistication and flexibility of the system weighed up against its clarity to read (by musicians) and simplicity to programme (by composers) that suggest this could be not such a trivial task after all.

The solution used for Flood Tide and Hour Angle was to design our own. At present LiveNotation is written in SuperCollider to interface easily with the algorithmic composition aspects of Flood Tide and Hour Angle. LiveNotation is essentially a graphics programme and requires little sound facility and we are considering whether it could be better developed in another programming environment such as Java.

As a general rule the design emphasis for LiveNotation is simple, limited, robust functionality that accepts our own simple data protocol to communicate the musical data generated.

A basic list of functions for an instrument notation window is:

- Instrument name
- Tempo (any)
- Meter (1 or more crotchet beats per bar - limited by width of window. Typical maximum 12)
- Clef (treble, alto, bass or treble and bass)
- Transposition
- Crotchet notehead or rest
- Playing instruction (one per bar)
- Dynamic marking (one per bar)
- Displays one bar per line of stave
- 1 or more lines of stave (typically 3). Lines of stave scroll upward.
- Cursor moves across top line.

LiveNotation permits the display of only basic musical notation. This is partly due to limited computer programming ability and partly because of differences in the function of a live notation system and conventional notation. LiveNotation typically shows three bars of music, each on a separate staff. The staff on the top line of the display is the current bar and has a cursor which moves across the bar to show musicians where the beat is. Bars 2 and 3 on the next lines down are the next bars to play and allow the musician to look ahead. In the image above the computer display is further broken into two separate instrument notation windows (i.e. one of marimba and one for vibraphone) on the left and right of the screen.
There are some huge compromises here. Rhythmically the system shows only crotchet values, either notes or rests. While this is extremely limiting it has the advantage of being easy to read. Some rhythmic variety is achieved by using playing instructions such as “triplet” or “quavers” meaning ‘play the written note as a group of three triplets’ or ‘two quavers’ respectively. Despite these huge limitations on what can be displayed using LiveNotation it is our assertion that interesting music can be made. The attitude has to be accept the limitations and see what you can do with it anyway!

6. HARDWARE SETUP

Flood Tide See Further was performed using a Mac Pro upgraded with a full complement of 4 graphics cards each with outputs for 2 displays. This meant a total of 8 separated displays were available. Each display had 2 discrete LiveNotation windows permitting a total of 16 individual notation parts. The tide rate sensor is the Nortek Vectrino [12].

7. CONCLUSION

This paper considered sonification as a means of musical expression with reference to some leading practitioners. The sonification projects Flood Tide and Hour Angle were introduced with some description of their purpose and a catalogue and brief details about each event. The question of why to make music by sonifying data was raised and we argued that it is a way of drawing attention to the data as well as being an art form that has emerged from advances in computer technology. Some detail about the algorithmic processes used specifically in Flood Tide See Further were presented. In particular 5 main composition algorithms for tempo, rhythm, pitch, playing instruction and orchestration were detailed and some discussion about the way these algorithms interact to create rich, varied and coherent music. A brief discussion of the background to systems for real time generation of music notation was considered with an outline of our LiveNotation system used in these sonification works. Finally a brief description of the hardware setup used for the performance of Flood Tide Flood Tide See Further.

8. REFERENCES