CMMR 2019

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Welcome to CMMR 2019!

We are happy to welcome you to the 14th edition of CMMR in Marseille. This is the second CMMR event that takes place in Marseille, but in a slightly different context than in 2013, since the present edition is organized by the new interdisciplinary art-science laboratory, PRISM (Perception, Representations, Image, Sound, Music), which very much reflects the spirit of the CMMR conference cycle. PRISM hosts researchers within a large variety of fields, spanning from physics and signal processing, art and aesthetic sciences to medicine and neuroscience that all have a common interest in the perception and representation of image, sound and music. The scientific challenge of PRISM is to reveal how the audible, the visible and their interactions generate new forms of sensitive and/or formal representations of the contemporary world.

CMMR2019 will be the occasion to celebrate the creation of the PRISM and at the same time honor one of its co-founders, researcher, composer and computer music pioneer Jean-Claude Risset who sadly passed away in November 2016, only two months before the laboratory was officially acknowledged. A scientific session followed by an evening concert will be dedicated to him on the first day of the conference.

From the first announcement of the CMMR2019 we received a large response from both scientists and artists who wanted to participate in the conference, either by organizing special sessions, presenting demos or installations or proposing workshops and concerts. Among the 15 scientific sessions that will take place during the conference, eight special sessions that deal with various subjects from sound design, immersive media and mobile devices to music and deafness, embodied musical interaction and phenomenology of the conscious experience are scheduled. We are also lucky to have three internationally renowned keynote speakers with us during this edition: John Chowning, Professor Emeritus at Stanford University who will talk about his friend and colleague Jean-Claude Risset, Geoffroy Peeters, Professor at Télécom ParisTech who will talk about past and present research within Music Information Research and Josh McDermott, Associate Professor in the Department of Brain and Cognitive Sciences at MIT who will present classic and recent approaches to auditory scene analysis.

The artistic program that has been elaborated in collaboration with "n+n corsino" and GMEM includes a tribute concert to Jean-Claude Risset, scheduled on Monday evening, a virtual/augmented concert on Tuesday evening and a contemporary music concert on Wednesday evening. During the last evening, an interactive music concert will take place under the direction of Christophe Héral. Sound installations and a videomusic presentation are also scheduled during the conference.

Finally, in addition to the scientific paper, poster and demo sessions and the artistic program, five satellite workshops are programmed right after the conference on Friday October 18th.

We hope that CMMR2019 will be an unforgettable event for all of you, and wish you a pleasant stay in Marseille.

R. Kronland-Martinet, S. Ystad and M. Aramaki
The CMMR2019 symposium chairs

Geysir: musical translation of geological noise

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Abstract. The sounds of geological phenomena are generally noise. Wind, glaciers, oceans, streams, and other geological sounds present a vast content of frequencies that often obscures individual pitches or groups of pitches. However, noise varies from sound to sound with different pitch predominance and patterns. This variance contributes to the signature that makes several noise-sounds unique. In this study, the sound of one of the geysers in the Geysir system of the Haukadalur valley, 180 miles Northeast of Reykjavik, Iceland, is recorded and analyzed in multiple time segments, each with its own pitch predominance and, therefore, signature. The analysis is further adapted into a piece for seven spatialized pianists and electronics titled *Geysir*, which features the amplitude and predominant pitch class fluctuations throughout the geyser sample. This paper reports the process of the analysis and the compositional applications of the pitch class predominance analysis.

Keywords: Music Transcription, Mapping, Sonification, Ecoacoustics, Data Analysis, Algorithmic Composition, Music Information Retrieval

1 Introduction

Timbral analysis and musical translation of sound models derived from natural and human environments have established their place in instrumental music for the last fifty years. F.B. Mâche used the spectrogram to derive pitch information from analysis of a recorded sound in the early '60s [1]. "The train of thought he had elaborated became for many electroacoustic composers a conscious or unconscious aesthetic starting-point (e.g. musical landscapes and 'phonographies' in L. Ferrari's, M. Redolfi's, J.-C. Risset's and others' works)" [2]. He proposed "to bring together poetics and theory, and to show the advantages that there are in advancing an aesthetic project on the basis of a harmony with natural data" [3]. Since 1973, the French spectral composers worked with a similar "*ecological* approach to timbres, noises and intervals" [4]. A substantial part of their sound models generally derived from musical instruments with various degrees of harmonicity/inharmonicity in order to generate harmonic, motivic and structural foundations for instrumental music based on analyses of their harmonic spectra.

Geysir traces its lineage to three particular works from what Anderson calls the third phase of the spectral tradition [5], when spectral composers extended their territory to larger collections of sonic objects [6]: Murail's *Le partage des eaux* (1995) that analyzes the sound of a wave crashing on the shore to generate material for orchestra [7]; *Bois Flotté* (1996)*,* Murail's sequel to *Le partage,* that analyzes sounds of waves, swells and undertows to generate material for trombone, string trio, piano, and synthesized sounds [8]; and Ablinger's *Quadraturen IV* (1998), that analyzes a Berlin urban soundscape characterized by noise to generate material for a large ensemble [9].

In these works, as in *Geysir*, the analyzed sound model is geological noise. The higher degree of complexity in geological noise results in higher and more random quantities of data than that resulting from spectral analyses of harmonic sounds. In order to compose with geological noise sound models, it is necessary to simplify the mass of information. Fineberg explains how Murail achieved this in *Bois Flotté* through a reduction in the number of analysis-derived chords by re-sampling the sequence, decomposing it into narrow spectral slices, and quantizing the pitches [10].

Geysir adds to the contributions by preceding composers in its field by proposing a methodology that merges spectral analysis, statistical analysis, and performance indeterminacy. Like its predecessors, the analysis and compositional strategies for *Geysir* aim to embody the complexity of noise while at the same time simplifying it in order to reveal salient features of the sound model and make the music not exceedingly difficult to perform.

Re-synthesis derived partial tracking, explained below, was used for the initial stage. The re-synthesis process included octave segmentation and the deletion of partials below an amplitude threshold. Notation prototypes derived from the re-synthesis were generated in IRCAM's Open Music [11], yielding material of a high degree of complexity (see Fig. 1).

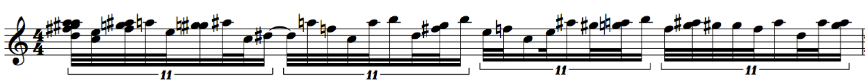

Fig. 1. staff 3 (C5-B5), 0:00-0:03, determinate partial tracking-derived notation

Considering the sound model's constant density and saturation from beginning to end, the performers would have had to sustain the rhythmic characteristics of this measure throughout the ~10-minute piece. From a perceptual perspective, the brevity of the rhythms paired to the saturation of the pitch sets was heard as a random mass of sound instead of auditory streams. The performance challenges of the material in addition to its aleatoric sound led to considering indeterminacy procedures for performance and rehearsal time economy. The indeterminacy consisted in having the performers generate the rhythmic material in a guided-improvisatory manner, with precise instructions regarding the pitch content, target rhythmic densities and dynamics. This idea led to a further distillation of the sound model: the calculation of pitch predominance at any desired point in time, organizing the pitches in three categories: high, medium and low predominance. The calculation was based on the total pitch count and durations per groups of measures, which provided the target rhythmic densities for each section. The pitch categories were assigned to specific note-heads (see Fig. 2).

Fig. 2. staff 3 (C5-B5), 0:00-0:03, indeterminate pitch-predominance notation

Figure 1 features the first four seconds of the geyser in the frequency range between 523 and 1047 Hz (C5-B5) with determinate notation, while Figure 2 features an abstraction of the first 16 seconds of the same frequency range with indeterminate notation. The differences between the resulting music from the two notation versions were strikingly low. The sonic signature of the salient predominant pitches and the rhythmic density of the section were preserved in the indeterminate notation version, and the material was made more accessible for performers.

A significant byproduct of the pitch-predominance analysis and resulting indeterminate notation was the increased potential of the material to be embodied by the performers. Their agency with the indeterminate material established a closer connection to the sound model, and therefore to the geyser.

The following sub-sections will explain the processes for the geyser's pitch, rhythm and dynamics analyses and translation into music for seven pianists and electronics.[1]

2 Frequency Region Segmentation and Partial Tracking

Using the Sinusoidal Partial Editing Analysis and Resynthesis (SPEAR) software [12], the audio recording was resynthesized in order to manipulate, organize, and calculate the predominance of the frequency content (see Fig. 3).

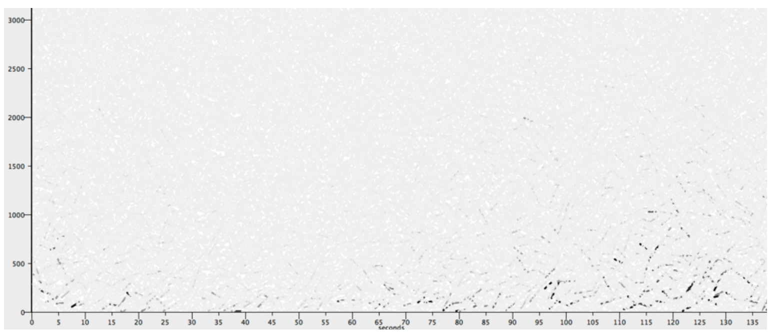

Fig. 3. Geyser analysis, entirety of re-synthesized partials until 2:15

[1] Full documentation of the analyses and audio examples referred to in the following sections available at http://www.christopherlunamega.com/works/analysis/geysir-analysis [13]

The audio was segmented in seven regions, from high to low, equivalent to a piano's seven complete octaves, from the lowest (C1) to the highest (C7). Each of these regions became an independent file (see Fig. 4). In each region, the partials with the amplitudes under -45 dB (the quietest) were eliminated, leaving only the loudest ones (see Fig. 5).

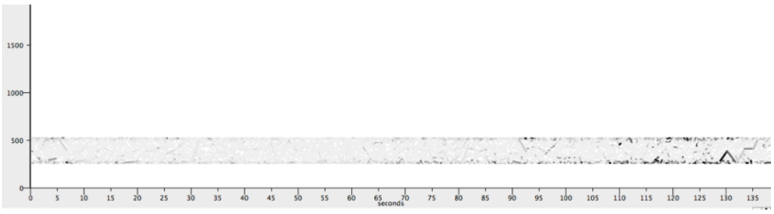

Fig. 4. Geyser analysis, segmented region (262-523 Hz)

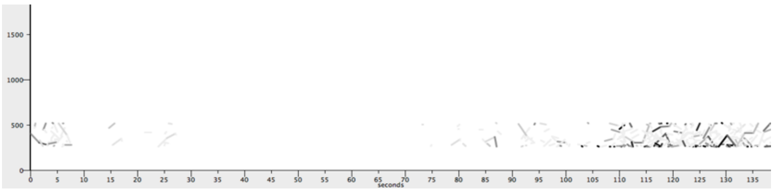

Fig. 5. Geyser analysis, segmented region after elimination of partials -25 dB

The sound data was converted from the SPEAR Sound Description Interchange Format (.sdif) into a text file (.txt) with IRCAM's Orchidée computer aided orchestration software [14]. Using Max MSP's Bach object library [15], the re-synthesized audio data encoded in the .txt file was then converted into music notation via partial tracking. A tool was generated for quantizing the complex rhythms and micro-tonal tunings of the geyser into simple rhythms adequate for pulse/time reference and the chromatic equal-tempered tuning system.[2] The resulting quantized audio data was translated into Music Exchangeable Markup Language format (.xml), making the contents compatible with data applications and music engraving software such as Sibelius or Finale.

[2] Equal-tempered tunings were chosen due to the fact that the music resulting from this analysis would be written for seven pianos. Quantization choices will vary depending on the affordances of the instruments that will perform. String instruments and some wind instruments can perform micro-tonal divisions up to 1/8 of a tone, as opposed to the piano, tuned to equal ½ of a tone.

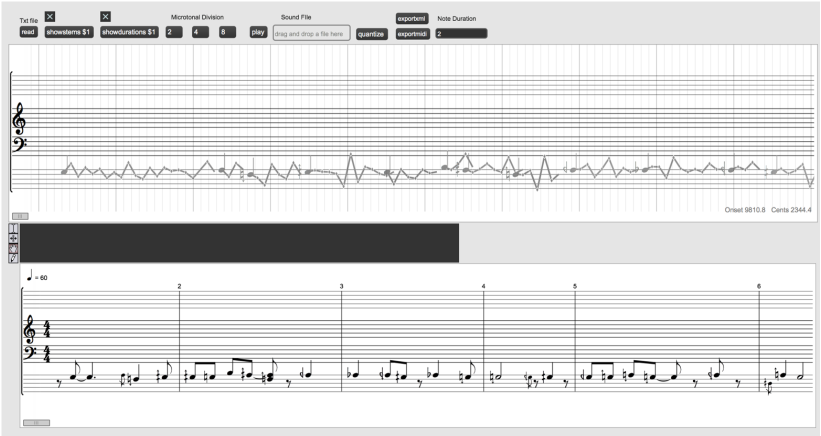

Fig. 6. Max MSP patch, including the bach.roll, bach.score, quantization, and .xml conversion tools[3]

3 Pitch Class Predominance Analysis

The last phase of the pitch analysis was the classification of the geyser's pitch classes derived from the previous processes. Using the BaseX database engine, all the pitches in the .xml file were organized by predominance and octave under the criteria of onset count and duration. A custom XQuery script [16] grouped the pitch classes and added the total time of their total onsets within a specific time segment (i.e., 16 onsets with a total of 20 seconds within a 25 second segment). Lastly, a list in descending order from most prominent to least prominent was generated for time intervals varying between 12 and 24 seconds. The lists derived from this analysis were then adapted entirely into the musical score for *Geysir*, for seven spatialized pianists and electronics.

3.1 Pitch Class Predominance Analysis Key

The information provided in this section is a description of each of the elements of the output from the XQuery script, which contains the distilled data used to inform the final scoring (see listing 1).

Listing 1. Pitch predominance data for staff 1 at 0:00-0:20

```
<group staff="1" measures="1,2,3,4">
 <pitch value="C#" duration="1920" count="15" rank3="high ●" rank4="high ●"/>
 <pitch value="C" duration="1408" count="11" rank3="high ●" rank4="medium ◇"/>
 <pitch value="Eb" duration="1280" count="10" rank3="medium ◇" rank4="medium ◇"/>
 <pitch value="D" duration="1280" count="10" rank3="medium ◇" rank4="medium ◇"/>
```

[3] The Max MSP programming was developed by Maxwell Tfirn [17].

```
<pitch value="F" duration="896" count="7" rank3="medium ◇" rank4="low ✕"/>
<pitch value="E" duration="256" count="2" rank3="low ✕" rank4="ruled out Ø"/>
```

Octave segmentation. The staves in the listing were numbered based on the initial octave segmentation performed in SPEAR.

- staff 1: C7 (piano 7) 2093-4186 Hz
- staff 2: C6 (piano 6) 1047-2093 Hz
- staff 3: C5 (piano 5) 523-1047 Hz
- staff 4: C4 (piano 4) 262-523 Hz
- staff 5: C3 (piano 3) 131-262 Hz
- staff 6: C2 (piano 2) 65-131 Hz
- staff 7: C1 (piano 1) 33-65 Hz

Pitch categories by predominance. The data shown in the listing displays pitches with calculated predominance in each octave, from highest to lowest, within the noise of the geyser. These pitches are labeled using four predominance categories: high (●), medium (◇), low (✕), and ruled out (Ø). These encodings were kept for the performers in the musical score.

Time. Time is presented in measures. Each measure is 4 seconds long, and the listing shows calculations over grouped measures. For example, in the first segment of the analysis (i.e., `<group staff="1" measures="1,2,3,4">`), each measure is 4 seconds long, so that the total time of measures 1, 2, 3, and 4 is 16 seconds. The temporal location of a measure is one less than the measure number multiplied by 4. For example, the time location of measure 30 is second 116, or time cue 01:56 (i.e., the first measure in `<group staff="1" measures="30,31,32,33,34">`).

Syntax. Each syntactic attribute in the document represents a specific feature used in the final scoring.

Table 1. Elements of the pitch predominance analysis

Feature	Description
Group staff	The octave analyzed (highest octave is group staff "1")
Measures	The total amount of measures in the segment analyzed
Pitch value	The pitch equivalence of the partial's frequency (e.g., 2218 HZ = C#)
Duration	Total duration of the partial's occurrences in the segment. The duration is displayed in milliseconds (1,920 milliseconds = 1.9 seconds)
Count	The number of iterations of the given pitch or frequency in the segment
Rank	The assessed predominance (low, medium, high). The "rank3" attribute is calculated from more pitches than "rank4", which filters out some pitches based on low counts/durations.

3.2 Pitch Class Predominance Analysis in Music Notation

The syntax of the analysis document (see Listing 2) was then converted into corresponding pitches on scored measures (see Fig. 8). The staff numbering translated into the register according to the octave segmentation shown above (staves 1-7 for C7-C1, respectively). The predominance ranks were mapped into note-heads with the same symbol (e.g., ● indicating a high predominance).

Listing 2. Pitch predominance data for staff 5 at 1:23-1:32

```
<group staff="5" measures="21,22,23,24">
 <pitch value="F#" duration="8320" count="64" rank3="high ●" rank4="high ●"/>
 <pitch value="Ab" duration="2816" count="21" rank3="low ✕" rank4="low ✕"/>
 <pitch value="G" duration="2560" count="20" rank3="low ✕" rank4="low ✕"/>
 <pitch value="E" duration="2176" count="17" rank3="low ✕" rank4="low ✕"/>
 <pitch value="F" duration="1408" count="10" rank3="low ✕" rank4="ruled out Ø"/>
 <pitch value="B" duration="1152" count="9" rank3="low ✕" rank4="ruled out Ø"/>
 <pitch value="C" duration="896" count="7" rank3="low ✕" rank4="ruled out Ø"/>
 <pitch value="Bb" duration="640" count="5" rank3="low ✕" rank4="ruled out Ø"/>
 <pitch value="A" duration="384" count="3" rank3="low ✕" rank4="ruled out Ø"/>
 <pitch value="D" duration="128" count="1" rank3="low ✕" rank4="ruled out Ø"/>
 <pitch value="C#" duration="128" count="1" rank3="low ✕" rank4="ruled out Ø"/>
```

Fig. 8. Corresponding scoring for staff 5 at 1:20-1:36

4 Rhythmic Density Derived from Pitch Predominance

Six categories of rhythmic density are used in the scoring. The frame of reference is one second. The number of attacks per second defines the rhythmic category, as expressed below:

𝅗𝅥	not more than one note per two seconds		not more than four notes per second
♩	not more than one note per second		not more than eight notes per second
	not more than two notes per second		as many notes as possible per second

As mentioned in the introduction, the rhythmic density categories were derived from the pitch predominance analysis. The "duration" attributes in the pitch-classification listings in the previous sections (3.1, 3.2) informed the rhythmic density categories. Duration refers to the total time in milliseconds that the pitch is sounding in a segment of time.

The total duration was divided by the total number of seconds of the bars considered in the segment. For example, staff 1 presents C# as its most prominent pitch in measures "24, 25, 26, 27, 28, 29", with a total duration of 13,184 milliseconds (13.18 seconds) throughout the six measures. The duration per measure is 4 seconds. Therefore, the total duration of the 6-measure segment is 24 seconds. The 24 seconds of the segment divided by the 13.18 seconds in which C# is sounding results in an average rhythmic proportion of 1.8. Therefore, the rhythmic density for bars 24–29 is low, of not more than one note for every 2 seconds. At other points of the piece, the rhythmic density is quite high as the energy of the geyser and therefore its amplitude increases. In this sense, the amplitude contour of the sound model is generally connected to the rhythmic material of the piece.

As noise-derived harmony may result in what Grisey termed as "neutralization of pitch"[5] [4], the rhythmic density categories derived from pitch predominance, as well as spatialization, were implemented not only for the avoidance of monotony, but for perceptual clarity.

5 Amplitude Analysis

The seven re-synthesized frequency segments processed in SPEAR were imported individually to a Digital Audio Workstation. A waveform display was generated in which the y-axis represents amplitude in dB (decibels) and the x-axis represents time. A screenshot of each waveform display was segmented into seven dynamics regions: ***ppp***, ***pp***, ***p***, ***mp***, ***mf***, ***f***, ***ff***. A drawn contour was used to track the dynamic evolution of the geyser's frequency regions through time (see Fig. 9). Each of the frequency regions' contours was transcribed to each of the seven parts of the score.

The dynamic contours of the frequency regions with lowest amplitudes–staff 1 and staff 7, which present the highest and lowest frequencies–were occasionally altered for balance and intelligibility. For example, staff 1 presents a very brief peak at ***pp***, its highest amplitude in the entire 11 minutes of recording. For this reason, a sub-segmentation was made within the ***ppp*** range, where the highest peak is re-interpreted as an ***mp***. Figures of all staves are available in the *Amplitude contours by octave* pdf at http://www.christopherlunamega.com/works/analysis/geysir-analysis [13].

[5] Grisey was addressing the importance of new techniques that are necessary to avoid monotony.

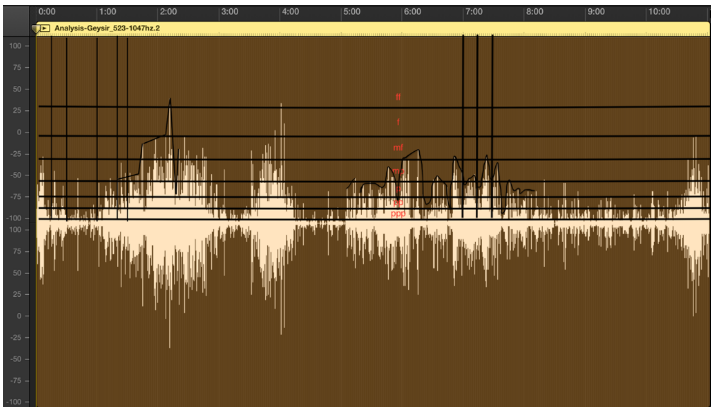

Fig. 9. Geyser analysis, staff=3 (C5–C6)

In the following example (see Fig. 10), the full score presents one of the overall peaks in amplitude in the entire 11-minute recording. A close look at the dynamics in each of the instruments will show the correspondences both in the macro-level and micro-level of dynamics: while there is a general increase in amplitude from 1:56 to 2:08, there are sudden dips and peaks in the dynamics within the overall increase in the section. The alterations in the dynamics of staff 1 and 7 are also evident in the example, in which the ***pp*** and ***p***, respectively, are increased to ***mp*** and ***mf*** in order to blend with the dynamics of the rest of the parts.

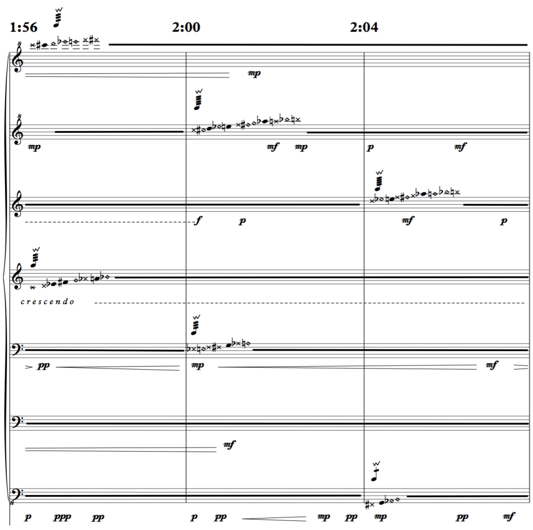

Fig. 10. *Geysir*, score excerpt

6 Notation

Each performer among the 7 pianists follows his/her part with a stopwatch. The pitch-predominance sets are introduced at varying intervals of time (between 12 and 30 seconds).

In the rhythm domain, the rhythmic value above the pitch-set determines the density that the performer will apply to perform the pitch set. The symbol placed above the rhythmic value means "irregular" (i.e., asymmetrical, uneven). The instruction to play irregularly is generalized in the entirety of the score, in accordance with the complexity of the sound model.

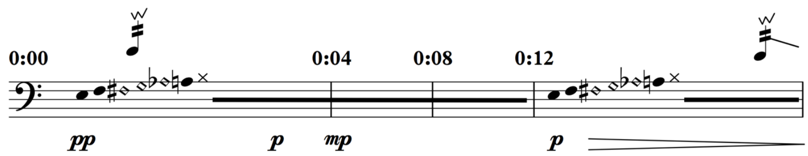

Fig. 11. *Geysir*, opening four measures, piano 5

The performer's choices are 1) the ordering of the sequences of the pitches included in the sets; 2) the durations of the irregular rhythmic values (in the example above, four notes per second, irregularly). The combination of these variables results in a variety of phrases that are generated by the performers, while preserving the essential features of the sound model (i.e., frequency, rhythmic density and amplitude contents).

7 Electronics / Spatialization

7.1 Spatialization

The electronics for the piece consist of seven-channel spatialized fixed media and telematic/live performer amplification. Due to the complexity of the sound model of the geyser and the music generated from it, spreading the streams of audio around the listeners was intended for perceptual clarity. The setup may vary depending on the venue, from a circular distribution of the speakers and all the performers (if the piece is performed in a flat level venue such as a museum), to a half circle distribution of the speakers, two performers on stage and five telematic performers. The latter version is the most viable for traditional concert halls and was the option for the premiere of the piece. The diagram for the setup is the following:

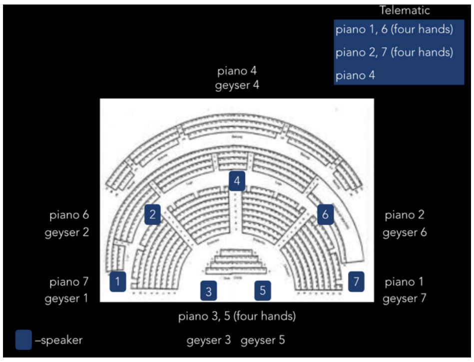

Fig. 12. *Geysir* spatialization diagram

Each speaker projects two sound sources: 1) telematic/live amplified piano; 2) a frequency stratus of the geyser sound model (explained below). There is one piano on stage, to be performed by two pianists playing piano 3 and piano 5, respectively. The other five pianists (pianos 1, 2, 4, 6, and 7) performed in piano cubicles situated outside the concert hall, in the University of Virginia's Department of Music. Their sound was sent to the concert hall using XLR cables and their image was broadcast live through a live video application projected on a screen on stage.

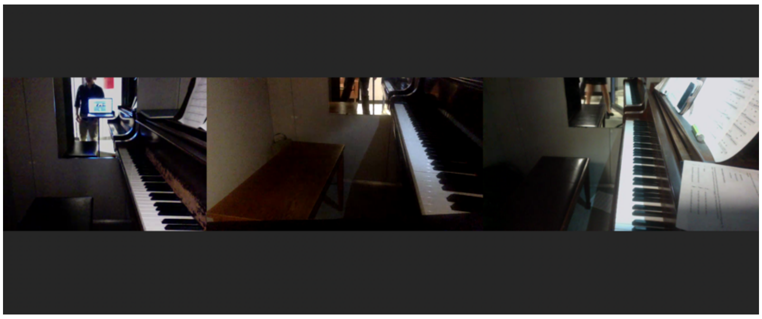

Fig. 13. *Geysir* telematic pianos

7.2 Fixed Media / Instrumental Pairing

Each of the seven tracks in the fixed media consists of a specific frequency stratum of the field recording of the geyser from which the piano parts are derived. Each track corresponds to the frequency range of each of the piano parts, based on their octave segmentation (see 3.1).

The spatialization diagram shows how each speaker projects two different audios containing different frequency strata. For example, Speaker 1 projects: 1) track 1 of the fixed media (the highest frequency region of the sound model) and 2) piano 7 (the lowest frequency region of the sound model-derived material). This approach was employed to balance the frequency distribution throughout the concert hall.

The score presents specific information regarding onsets/offsets of the tracks, as well as dynamics for both the fixed media and the live performers on the mixer.

7.3 Fixed Media–Live Instruments Amplitude Contour

The seven tracks in the fixed media do not sound simultaneously throughout the piece. Each track fades in and out of the mix in order to open the listening field to different frequency regions over time. When the general amplitude contour of the sound model is low, there is a small number of tracks active. Similarly, although not systematically, a larger number of tracks is active at the points of highest amplitude.

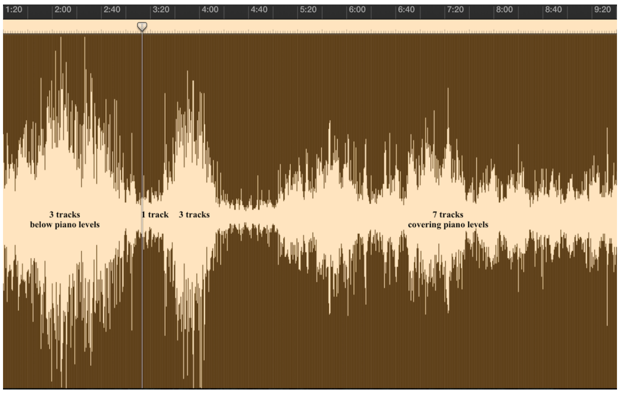

Fig. 14. Geyser analysis, general amplitude

The overall form of the piece has a general distribution of track density from lower to higher, all tracks being active for the last two minutes of the piece. The simultaneity of all tracks presents the sound model of the geyser at its full extent in an immersive spatialized environment. As this happens, the dynamics and amplification of the pianos subside, while the levels of the recording of the geyser in the fixed media are increased. By the last minute of the piece, the fixed media is the prevailing sound. The conceptual and poetic intention behind this formal plan was that the performers, who begin the piece with no electronics, gradually embody the sonic features of the geyser until they have become it. The electronics design is, in this sense, a representation of our philosophy of sound model-based composition: the embodiment of natural principles through the analysis of its sonic features.

8 Future Development

The modeling and scoring process could be improved by decreasing the required number of analytical manual steps. This could help musical authors develop scores based on similar phenomena with a broad spectrum of notes of highly-variable predominance. Other improvements could focus on the sound model itself, constructing a generalization of the sonic information to produce randomized scores with related sonic qualities. Finally, from a purely aesthetic point of view, a future compositional piece could explore less prominent frequencies.

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