SONATA FOR CASSIOPEIA: A PARAMETER MAPPING MUSIFICATION STUDY FOR PIANO AND STARS

Gregorio Panerai

P.O.Box 457, Pistoiese St, Firenze, Italy
gregorio.panerai@gmail.com

ABSTRACT

This paper explores the use of sonification as a tool for music composition. The chosen data for this research were the main features related to the stars belonging to the constellation Cassiopeia. The processed characteristics are the spectral classification, luminosity class, apparent magnitude and the distance from Earth. Each star was converted into a musical note with a certain register, intensity and a specific time location. This process led to the creation of a piece for piano and electronics that seeks to combine an effective sonification strategy for data representation and the creation of an evocative musical dimension. The concept of this work is to integrate the use of sonification in the composer practice as a tool for production, prototyping and exploration of musical elements and structures. One of the goals is to encourage the composers to dynamically experiment sonification techniques and different mapping strategies according to their musical taste during the composition process.

1. INTRODUCTION

Sonification is defined as the data-dependent generation of sound, if the transformation is systematic, objective and reproducible [1]. Musification, on the other hand, can be described as the musical representation of data [2]. A more detailed definition of what kind of sonic material can be defined as musical is needed, and more in general a definition of what music is. Trying to expand Edgar Varèse definition [3], music can be defined as the art of organizing sound to convey emotions trough sonic events leading the human mind to the perception of gestalts. Without exploring the complexity of the Gestalt theory, it's possible to describe the concept of a gestalt adopted in this work as a mental metaphor for a musical gesture. Therefore musification can be supposed to be an empathic sonification [4]. As described by Coop [5] it's also possible to say that musification is a process specifically designed to go beyond direct sonification and include elements of tonality and the use of modal scales to create musical auralizations. The purpose of this research is to implement and test a sonification strategy able to compose music, expressing data trough instrumental sound gestures. Some of the most important works on this topic are obviously those of Marty Quinn [6], which pioneered a first real attempt to create music using sonification as a compositional tool. More recently it's possible to listen sonifications of NASA's space telescopes images made by System Sounds [7]. The technique used in this work, called parameter mapping sonification, involves the association of information with auditory parameters for the purpose of data display [8]. A data parameterization strategy translate each star into a given piano note by transforming its main features into specific frequency, amplitude and time location in the piece. The main challenge of this research is to combine a systemic objectivity for data transformation into sound to the creation of musical semantic elements, trying to reconfigure sonification from an instrument solely for scientific enquiry into a mass medium for an audience with expectations of a functional and aesthetically satisfying experience [9].

2. DATA

The first data used for this research come from the spectral classification of the main stars of Cassiopeia. Two types of classification were used for this process: the Harvard spectral classification and the Yerkes spectral classification, also known as the MK (Morgan-Keenan) system. The Harvard classification, developed at the end of the 19th century and revised to its present form in the 1920s, classifies stars according to their surface temperature and provides a division by chromaticity. Therefore 7 spectral classes were obtained as shown in Fig .1.

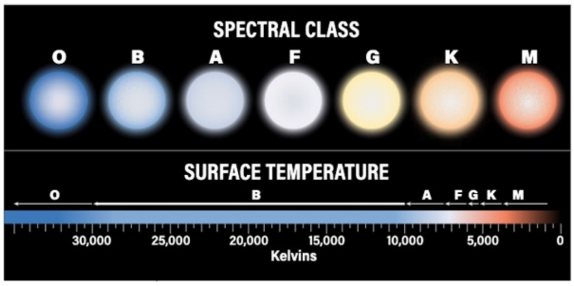

Figure 1: Spectral classification of stars based on surface temperature [10]

In the MK system the stars temperature and the surface gravity provide a division into eight luminosity classes (some of which have subdivisions not considered in this paper) [11]:

- Hypergiants, class 0
- Supergiants, class I
- Bright Giants, class II
- Giants, class III
- SubGiants, class IV

- Dwarves or Main Sequence, class V
- Subdwarves, class VI
- White Dwarves, class D or VII

A useful tool to understand the spectral classification of a star is the Hertzsprung-Russell diagram, made in the early 1900s by Ejnar Hertzsprung and Henry Norris Russell, which relates the temperature of a star to its luminosity as shown in Fig. 2.

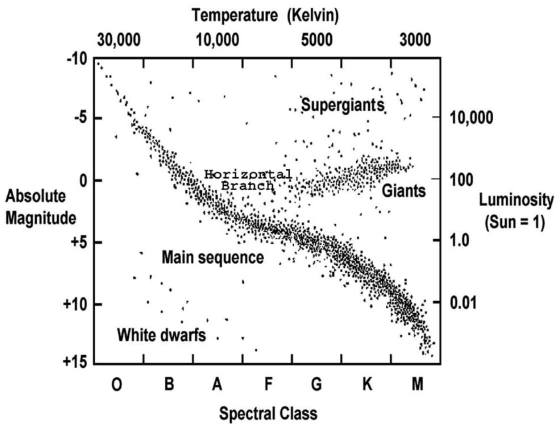

Figure 2: The Hertzsprung-Russell diagram [12]

Fig. 3 shows some examples of stars spectral features classification.

B8.5 III
A7 III−IV
F6 V
A2 Va
A3 IV−V

Figure 3: Spectral classification examples

No further subdivisions were considered in the description of spectral peculiarities such temperature sub-classes or elements relating to the emission details of the star. The other two factors used in this work are the distance from the Earth, expressed in light-years, and the apparent magnitude, that is the brightness of a star or other astronomical object observed from Earth. The data were obtained from the Astronomical Almanac 2000 [13].

3. PARAMETER MAPPING STRATEGIES

A mapping strategy in sonification can be defined as a function from the data domain to the auditory domain [14]. The mapping strategy adopted in this work use a symbolic and interpretative approach to data representation into the sound domain. Referring to Vickers and Hogg [15] it's possible to describe the system adopted as a low indexicality one. The four data types of each stars were mapped to three midi parameters to control the note generation. Looking at the Sonification Design Map developed by deCampo [16], it's possible to notice how sonifications that use notes are those that require the smallest number of data point streams for gestalts perception. The technique adopted in this research can be classified as a parameter mapping, event based and discrete point sonification.

3.1. Midi Note

The selection of the note to play is controlled by the two spectral features mentioned before. The first point is the choice of the octave in which the note should fall. The octave of the note is selected by the Harvard spectral classification parameter. The available octaves were limited to six excluding the higher ones, to maximize the perception of melodic sense due to the nature of human ear [17]. Having only six octaves available, the seven spectral classes were reduced combining O and B, both of which are very hot, in the same one. The temperature of the stars was mapped to the register of the pitch with a "positive polarity" where, as described by Neuhoff [18], increases in the value of one dimension of the data are represented by increases in the pitch. The lowest octaves were associated to the stars tending towards to red (colder), while the highest ones to the stars tending towards blue (hotter) in the following way:

- class M, 1
- class K, 2
- class G, 3
- class F, 4
- class A, 5
- classes O-B, 6

The second point is the selection of one of six scale degrees. This choice is the result of various attempts that took into account the author's musical taste and the effectiveness of perception of melodic and harmonic structures. The MK luminosity classification was responsible for the selection of one of the scale degrees. As for the octave selection the luminosity classes were reduced to a total of six, Hypergiants and Supergiants, as well as Dwarfs and Subdwarfs were included in the same categories. A number representing the chosen scale degree expressed as music interval was associated for each of these six new classes.

- classes O-I, perfect unison, 1
- class II, major second, 9/8
- class III, major third, 5/4
- class IV, perfect fifth, 3/2
- classes V-VI, major sixth, 5/3
- class D, major seventh, 15/8

A reference note was selected to be the lowest executable, namely an A at 55 Hz and the frequency of the star's note was obtained using the following formula:

$$f(i) = f(b) * l(i) * 2^{(s(i)-1)} \quad (1)$$

where f(i) is the note frequency, f(b) is the lowest frequency note at 55 Hz, l(i) is the ratio corresponding to the musical interval derived from the MK luminosity classification and s(i) is the chosen octave according to the Harvard spectral classification. The resulting numerical value in Hertz was then converted into the corresponding midi note.

3.2. Midi Velocity

The data associated with this parameter is the apparent magnitude of the star, or the brightness of an object as it appears in the night sky. This value for the main stars of Cassiopeia falls between 2.24, the brightest star called Shedar, and 12.24, the least visible one from Earth. Using this data to control midi velocity, the stars magnitude controls the amplitude of the note, making the more visible ones louder. The 128 possible midi velocity values were reduced between 14 and 82, obtaining a dynamic range between a piano-pianissimo (ppp) and a mezzoforte (mf). A wider velocity value's range would certainly emphasised the differences in magnitude but, once again degrading the sensation of pleasure in the listening experience.

3.3. Tempo

The time location of a note in the piece is determined by the distance in light years of a star from the Earth. According to the time spent by the light to travel through space, as mentioned by Bardelli, Ferretti, Presti and Rinaldi [19], a piece with such tempo/space relation can be imagine as a journey back in time. Starting from the closest ones, few dozens of light years away, will be listen up to stars distant thousands of light years. At this stage of the project the proportion adopted is 1 light-year : 0,1 second.

4. SOUNDS

The technical realization of this work is the result of the interconnection between several blocks. The core of the project is a code to read and elaborate the data, written in the Supercollider language, an object-oriented textual programming software and a powerful tool in the development of sonifications and sound design. After loading and reading the prepared data with a similar procedure like the one proposed by Bovermann, Rohrhuber, and deCampo [20], Supercollider behaves like a midi sequencer sending events to the receiving digital audio work station (DAW) where the piano samples were loaded and ready to be played. Just minimal corrections have been applied to the equalization of the piano instrument and no dynamic's processor, like a compressor or limiter, was used on the dynamic range. At last a long reverberation was used to increase the instrumental evocative power and to provide spatial depth to the sound.

4.1. Spectral Freezing Drone

The creation of this instrument arose from the need to keep track over time of the spectral characteristics of the stars. It was import to create a kind of unique sound signature represents the totality of a constellation's stars. This sound signature is created as an harmonic snapshot, like an infinite chord, a sum of all the midi notes played. The plenty of harmonics in the spectrum due to the piano timbre, would create a too dense and confusing drone. A pure sinusoidal oscillator was created with a determined envelope duration of two seconds, which synchrony receiving midi events with the piano. The freezing effect is then applied to this oscillator with a technique called Fourier Analysis and Resynthesis, looping some analysis windows of a Fast Fourier Transform (FFT) of the audio signal. For details on this technique refer to Miller Puckette's fundamental work "The theory and techniques of Electronic Music" [21]. Thanks to slight oscillations caused by a randomization of phase values and to the division into frequency analysis bands of the audio signal, a much more interesting and evocative sound was obtained than a pure sinusoidal additive synthesis.

5. RESULTS

The result is a fifteen minute long (circa) piano and electronic piece. The decision made for the sonification's strategies and the choices of sound material were guided by the search for an ambient music soundscape with a minimalist aestethic. The sonic result was therefore designed to create a contemplative and intimate dimension more related to the work of Brian Eno [22] than to a traditional piano composition. Through the sonic impression created by the drone, it is possible to immediately compare different constellations. In Fig. 4 are shown the drone's spetctral signatures of three constellations: Lyra, Ursa Major and Cassiopeia.

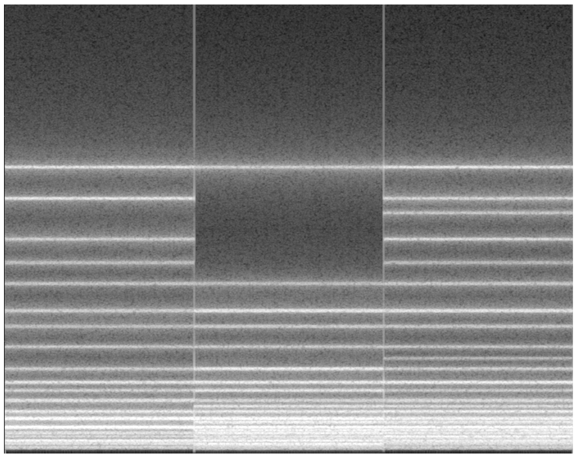

Figure 4: Spectral signatures of Lyra, Ursa Major and Cassiopeia

From this spectrogram it is possible to see how a listener differently perceive the three constellations and draw some immediate conclusions. For example, due to the large harmonic concentration in the lower register, it's possible to perceive the greater number of red and orange stars and the lack of some blue and white in Ursa Major compared to the other two constellations. It also shows how Cassiopeia has a wider distribution of stars types than Lyra. Listening to the spectral and harmonic morphology of the resulting drone gives, as mentioned above, the progressive overview of a constellation stars distribution. The temporal distribution of the events and the notes different amplitude create the perception of musical accents, phrases and rhythmic syntagmas. From a musical perspective it's possible to notice, for example, that the perception of chords represents stars at the same distance or the presence of a binary or ternary system. The stars spectral features creates a melodic development feeling, that thanks to the rhythmic interactions between the events, gives the listener the perception of a layered harmonic evolution. It can be notice a progressive rarefaction of the note events and a preponderance of the drone, until we reach the most distant star. Such rarefaction emerged from the distribution of the stars distances from Earth. It works a compositional and narrative expedient presenting the vastness of sidereal space and the remoteness from our planet, metaphorically giving the idea of a kind of an astral solitude.

The audio material is available at: `https://zenodo.org/record/7858273#.ZE1LmuxBz0o`.

6. FUTURE WORKS

This work is a starting point for a wider artistic and personal research into the use of sonification as a tool for musical composition. The created system is a prototype for the composer exploration of rhythmic, melodic and harmonic solutions driven by data. The data parameterization choices and the synthesis of the sound material are the result of a personal musical taste balanced with the technical and acoustic expedients necessary for effective sonification. More constellations will be musified with the same technique presented in this paper for a larger scale comparison. More possibilities remain to be explored in data parameterization such a non-linear approach to the time, the use of different musical scales, intervals, modulations and different instruments. At last the implementation of an Ambisonics surround spatialization system will be explored to use 3D positioning as additional sonification parameter.

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