SONIFICATION OF ACE LEVEL 2 SOLAR WIND DATA

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ABSTRACT

This paper provides a brief overview of the sonification research conducted by the Solar and Heliospheric Research Group at the University of Michigan. The team collaborated with composer and multimedia artist Robert Alexander to gain a new perspective of the underlying patterns behind recurring solar wind phenomena. This sonification effort was one in which a high level of creative freedom was provided to the composer, while scientific accuracy was maintained through adherence to the original data set. An interface was constructed in Max/MSP that allowed ACE-SWICS Level 2 solar wind data to be graphed visually and represented aurally through both acoustic and synthesized timbres. This document will explore the sonification methods behind iteration 1.1, which is a sonification of solar wind activity from 2003.

1. INTRODUCTION

The solar wind, originating from the Sun and carried into interplanetary space, is highly dynamic and punctuated by abrupt explosive events. This dynamic nature provides the ideal medium to experiment with sonification. Iteration 1.1 is well suited for absorbing data over a long period of time. The listener should relax and allow their attention to drift between the various sounds. The algorithm has been refined to create a balance between all parts. This balance is punctuated by Coronal Mass Ejection (CME) events, which are explosions of vast amounts of material and energy from the Sun.

Upon first experiencing the iteration, it is possible to deduce the audio-visual correlation by closely viewing each individual data parameter as seen in Figure 1. These data parameters have been scaled to make full use of the visual space, and the maximum and minimum values used for this scaling are displayed below the data type. The original value is displayed in a number box to the left of the graphic representation. The data points included in this sonification are:

1) Helium (He++) density (1/cm^3)
2) He++ speed (km/s)
3) Carbon average charge state
4) Solar Wind Type (0. Streamer Wind 1. Coronal Hole Wind 2. Coronal Mass Ejection).
5) Helium to Oxygen (He/O) element ratio
6) Carbon charge state 4+
7) Carbon charge state 5+
8) Carbon charge state 6+

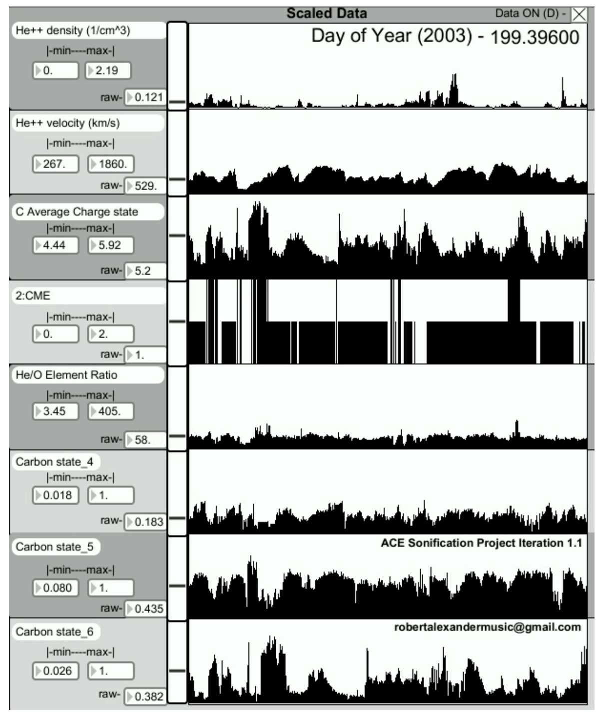

Figure 1: Visual representation of sonified data.

From Figure 1, the reader can see that some quantities vary more smoothly and are less variable, while other quantities vary quite drastically and often in unison with other parameters.

2. IMPLEMENTATION IN MAX/MSP

The data file used in this sonification contains a combination of 2-hour averaged solar wind parameters and 2-hour averaged charge-state distributions from the Solar Wind Ion Composition Spectrometer (SWICS) on the Advanced Composition Explorer (ACE), which orbits at the gravitational saddle point between the Sun and the Earth. These data sets are provided to the public by the ACE Science Center (ASC). The data is loaded into the "text" object in MAX and the "line" message is used to represent successive data entries. The minimum and maximum values of each parameter are used to scale the data, which is then plotted. Any 3 entries can be plotted next to one another for comparison purposes, and selected data can then be sent directly to the sonification section of the patch.

3. SONIFICATION METHODOLOGY

The section of the patch that was devoted to sonification began as a relatively blank-slate, such that ideas could be quickly implemented. This multi-layered sonification was constructed through an iterative process of experimentation with various data mappings. This section will deconstruct each element of the sonification.

The sweeping wind sound is generated by both He++ density and speed. The speed parameter controls the cutoff frequency of a band-pass filter, which causes the "whooshing" noise that sweeps up and down. The density parameter controls the loudness of this wind sound, i.e., the higher the density the louder the wind. The use of filtered noise creates a sound that is reminiscent of terrestrial wind phenomena. During a CME, the wind is further amplified and processed with a form of distortion known as overdrive. This causes the wind to swell in a more violent fashion. One particularly interesting moment occurs at 3:05, during an extended CME.

The different charge states of Carbon provide information on the temperature of the corona; higher charge states originate in a hotter region of the corona, often associated with CMEs. The basic vocal ambience layer is created with 6 distinct vocal layers that each correspond to a charge state of carbon. A recording of a female voice (alto vocalist Amanda Alexander) was conducted in a small room with a condenser microphone. Each note was recorded individually, and each file was subsequently edited to create one long extremely smooth tone. The prevalence of one charge state over the other, as determined by the distribution ratio, is used to modulate the gain of each vocal layer. For example, charge state 6+ (the bottom box) corresponds to the higher voices, which are panned to the left ear (this is easier to distinguish on headphones). As this charge state becomes more predominant, the higher voice will stick out.

Carbon charge states 4+ and 5+ are easily discernible by listening for the absence of charge state 6+. They occur as lower sets of voices that are panned to the right. The pitch cluster is reinforced by a set of sinusoidal tones at the same frequencies; the volume of these tones is linked to the predominance of Carbon charge state 4+. These tones are quite soft, but their presence significantly adds to the texture of the sonification.

The value "C Average Charge State" is represented by another set of voices that sing in a higher octave. The easiest way to pick these voices out is to listen during a Coronal Mass Ejection event; at this time the highest of these voices bends upward in pitch. A chord composed of an extremely high frequency set of triangle waveforms represents the He/O element ratio. This sound can be described as a "glistening," it clearly stands out during the CME at 3:07.

Solar wind type is the most readily discernible feature in this sonification. During a CME the reverb quickly swells to a much higher volume before slowly attenuating back to the original volume, which creates the feeling of a sudden expanse. The difference between Streamer wind and Coronal Hole Wind is subtler. During streamer wind the level of reverb is further attenuated, and the chanting vocal ostinato is cut completely. The soft vocal chanting layer doubles in loudness during a CME. The bass-line is also played two octaves higher during a CME; this sound quite muffled.

A Low-Frequency bass tone was generated with a saw-tooth waveform that traveled algorithmically between a pre-determined group of pitches. The changes in the bass not only mark time, but also provide a sense of forward momentum through harmonic progression (the movement of the bass creates a pseudo-random progression between I, ii, IV, and vi chords in C major). The change in pitch happens once every half sidereal Carrington rotation; two changes in pitch mark one full sidereal Carrington rotation (25.38 days). To further demarcate the rotation process, an automated low-pass filter was applied. The cutoff frequency of this low-pass filter travels up and down with one full rotation. During one half-rotation the bass sound becomes muffled (the cutoff frequency is lowered), and during the other half it is slowly un-muffled (the cutoff frequency is raised).

4. CONCLUSION AND FUTURE DIRECTION

The team was able to hear complex interactions between multiple data entries, but has yet to unearth any new findings from initial experimentations. The sonification work resulting from this project has gained wide attention due to its aesthetic appeal and scientific potential. For future iterations the team is interested in taking on larger time scales. The number of active sunspots could provide a potentially compelling arc in the sonification of a complete solar cycle. This sonification effort is still in its early stages, and the team is hopeful about the potential of future work in this area.

The technique has the potential for impact in two distinct ways. First, making numerical solar wind data into music can make it much more accessible the public at large. This is a long standing difficulty with data of this sort: While movies of solar explosions sometimes make into the evening news, few would consider including a bunch of wiggly lines. This project has already made strides in this direction, including posting online videos that includes solar wind composition data. With continued work, future dramatic sonifications could further inform non-scientists about the complex behavior of the sun.

Second, sonification has the potential to advance this scientific field by helping researchers to find patterns and features in the data that went undetected through other means. Humans have a well-refined ability to appreciate complex sonic environments and pick out individual details. The human brain has powerful pattern-detecting mechanisms; many scientific leaps in the past have sprung directly from human intuition. Custom-designed software tools that enabled researchers to build and vary sonifications in near real time, much like is currently done with visualizations, could potentially improve scientific understanding of the data and lead to new ideas for exploration.