PLANETHESIZER: SONIFICATION CONCERT

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1. MOTIVATIONS AND CONTEXT

The exponential increase on virtual instruments development and their popularity and establishment as part of the current workflow on audio productions, both in home studios and professional environments, open a new opportunity in approaching science to general public and designing audio tools based on physical or mathematical models of undoubted creative and artistic utility. Under this context, the publication of the discovery of seven Earth-like planets orbiting around the Trappist-1 star on February 2017, inspired the creation of a model-based virtual instrument. As result, the Virtual Interactive Synthesizer prototype *Planethesizer* is presented, which default configurations display a multimodal Trappist-1, Kepler-444 and a K2-72 planetary systems simulation. With the development of this astronomical data interactive sonification VST plugin, this work also tries to suggest a possible line of interdisciplinary audio tools development.

In an attempt to make a state of the art review in terms of astronomical data sonification and to analyze the technology, processes, tools and techniques that are currently involved in this field, results clear that Pythagoras (S. VI B.C.) and his *Music of the Spheres* as well as Kepler's *Harmonices Mundi* (1619), represent the crucial starting point of the relation between occidental music and astrophysics [1]. Highly influenced by this fundamental works, appear the animated sonifications of the solar system from Twyman (2010) [2], and Mark Ballora's sonifications for the film *Rhythms of the Universe* (2013) [3], a co-production of the ethno-musicologist and percussionist from the mythical band *Grateful Dead* and the cosmologist George Smoot III from *Lawrence Berkeley Labs*. Quinton, M. et al. [4] went a step further with their perceptual research on the solar system's sonifications created for the planetarium Esplora (2016, island of Malta), proposing a planet properties through sound recognition test, realized on both specialized and non-specialized audience. In this sense of probing the effectiveness of the astronomical data sonification processes, also highlights the work of Diaz Merced, W. L. (2013) [5], the *Supernova Sonification* [6] and the prototype *xSonify* project [7], built in collaboration with NASA. Trying to equilibrate creative freedom and scientific accuracy to the original data sheet, it's also worth mentioning the solar wind data sonifications of Alexander, R. et al (2010) [8].

In a more creative context, Winton et al. [9] developed the sonifications of stellar data from Kepler Telescope (2012), using *Sonification Sanbox* software [10] and *Matlab's* interpolation functions to explore the aesthetical possibilities of direct unprocessed conversions. Also interesting is the orchestral character coding sonifications of Quinn, M. for the exoplanets and stars information data base of the *European Southern Observatory* [11], and the mapping sonification work of Jamie Ferguson in collaboration with ESA *From Hipparchus to Hipparcos* (2014) [12], that translate several historic stars catalogues to sound in a way that reminds John Cage's *Etudes Australes*. Finally, it's impossible not to mention Tim Pyle's *Trappist Transits* musical representation (2017) [13], illustrating NASA's *Spitzer* Telescope data for informational purposes.

2. PLANETHESIZER CONCEPT

Planethesizer prototype was designed under the inspiration of Iain McCurdy's works [14], *LorentzSynth* (2015) and *Planet* (2012). It can be defined as a vector synthesis virtual instrument implemented from Csound's *Planet* opcode. This opcode or computing operation code, generates the coordinates (*x, y, z*) of a planet orbiting a binary star system simulation which outputs -calculated for each of the seven planets-, are used to control seven software synthesizers. The instrument also provides an additional eighth synthesizer, controlled through a real time MIDI keyboard that improves musical interaction. Csound [15] was used in combination with Cabbage front end [16] to implement a VST plugin and to maximize compatibility with any DAW (Digital Audio Workstation), both on Mac and PC computers. Blender software [17] was used for the graphic design of the star.

The prototype can be downloaded for testing from: https://archive.org/details/@agriber

A musical composition using Planethesizer in a creative context is also available from:
https://www.youtube.com/watch?v=gUfA7kF_P0k&t=18s

In order to maximize intelligibility and simplicity of calculation, in *Planethesizer*, every sound appears linked to the graphic simulation of its planet, forming a multimodal representation that minimizes its learning curve.

Figure 1 shows the prototype interface that allow end-users to control sound properties as function of the radius, semi-axis, inclination, period and impact factor for the orbit of each planet or synthesizer, expressed in astronomical units. To reproduce the eclipse sequence cadence, each planet can be initial delayed introducing time differences in days. Level control is allowed in master output, keyboard's synthesizer as well as in every planet's module. The *Restart* button initializes the eclipses sequence and the *Init. Delay Off* button deactivate initial delay, allowing to synchronize the orbiting planets of the simulation for creative porpoises. The prototype also includes a global tempo, global zoom control and one *on/off* button for each planet. Instrument default configuration represents a multimodal simulation of Trappist-1 system. Saving and recalling presets is also allowed.

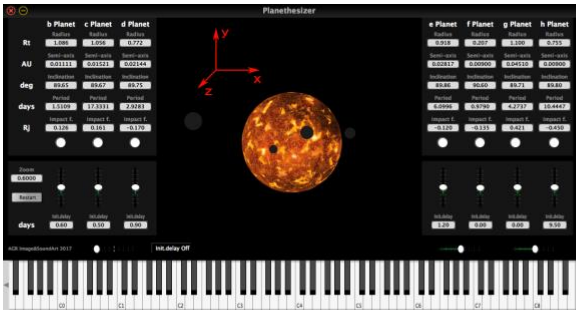

Figure 1: *Planethesizer* interface illustrating the axes used in the simulation's graphic display.

3. SOUND DESIGN AND CAPABILITIES

Intensive testing with *opcodes* described in Csound's database [18] was made to achieve Planethesizer's final design wich required a compromise solution between processing CPU load and sound richness.

Table 1. Csound opcodes, synthesis types and initial delay (days), used for Trappist-1 System Sonification.

Planet	Opcode	Synthesis	Delay
b	fof	Granular	0,6
c	Vco2 Moogladder	Wavetable LPF	0,5
d	buzz	Harmonic sinusoids	0,9
e	poscil3	Hi resolution sinusoid	1,2
f	poscil3	Hi resolution sinusoid	0
g	poscil3	Hi resolution sinusoid	0
h	hsboscil	Wavetable	9,5
Keys	foscil	FM	-

The sonification process was oriented to provide a clear auditory distinction of each periodic sound event represented in the simulation with the exception of planets *b* and *c*, whose intentioned similarity was focused to test their graphical recognition through spectrogram analysis. Planets *e*, *f* and *g* use identical oscillators that can be tuned to desired frequencies modifying planets' radius or impact factor. In this way, a chord of three notes can be generated, allowing a "desirable" fusion of the sounds. Starting from identical time configurations for the three planets, a synchronized sound block is generated allowing to observe how the graphic representation of the prototype loses its usefulness despite the auditory display still provides a clear differentiation of the sounds that conform the chord. In a similar way, Cocktail party effect can be experimented representing the hole system or focusing attention to a specific planet. The prototype also allows Haas effect monitoring acting over initial delay on two unison sounding planets. *Chords, Arpeggio, Unison, Cocktail* and *Haas* presets were included in the prototype for these application. As a creative musical add-on, it's also possible in the prototype to generate real time arpeggios by introducing an initial delay or switching *On/Off* button on desired module. Musical figures can be made controlling planet's speed through orbital period parameters.

4. SIMULATED VS MEASURED PLANETARY SEQUENCE

Once the prototype was completely implemented, the sonification of the Trappist-1 system was recorded and analyzed to test its behavior. The spectrograms of *Figure 2* obtained with Sonic Visualizer software [19], show the audio file content in frequency (vertical axis) and time (horizontal), with time in seconds and a frequency range of 80Hz to 22Kz in the upper graph, and 10Hz to 1500Hz in the low frequency detail spectrogram.

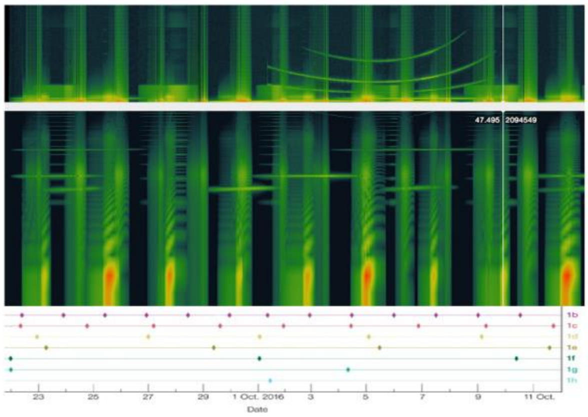

Figure 2: Comparison between the simulated eclipses sequence and the Trappist-1 system telescope observations published by Guillon, M. et al., 2017 [20]. Both spectrograms (top and middle) are related to same audio file and its frequency axis was split for a complete recognition of sound events.

Analyzing *Figure 2,* it's possible to appreciate how the simulated sequence matches the behavior of the observed exoplanets system -assuming no precision-, fact that suggests the possibility of predicting transit moments from the simulation prototype beyond the observed data, which might be useful for informative purposes.

5. DEMONSTRATION PROPOSAL

For the public presentation of Planethesizer, a live creative Sonification concert is proposed. The performance would consist of a continuous musical piece of five movements that explore the prototype capabilities interacting with a drum set, piano and some effects. The music would be composed *ad hoc* for the conference. *Figure 3* shows the instrumental set up needed, initially planned to be reproduced in a quadraphonic environment with live video projection of the prototype.

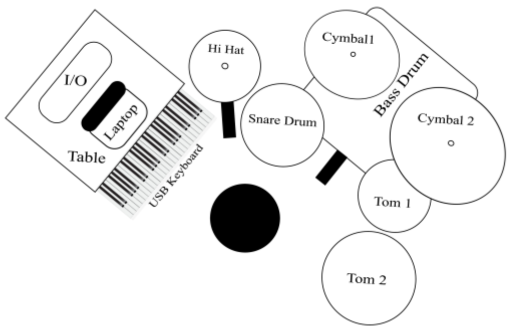

Figure 3: Stage plot for Planethesizer's demonstration concert.

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