LIVEDOG, INC.: *Hard Science* and *A History of Mathematics*

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ABSTRACT

Livedog, inc. is a performance project aiming to exacerbate the theatrical elements in live coding. Sonification underlies many pieces within a typical live set. In this document we discuss a group of sonifications under the title *Hard Science* represented by an algorithmic sequencer based on the periodic table of elements, a sonification of a Schwarzchild solution within general relativity, a quantum computer sequencer, and models of human hearing. Musical mappings are introduced for *A History of Mathematics* ranging from the Babylonian square root algorithm, through change ringing and Bürgi's 16th century sine calculation method, to Riemann's zeta function, abstract generalisations of the prime numbers, and the 3x+1 problem. Such musical works are intended for algorave performance, highlighting the musical consequences of our algorithmic world.

1. INTRODUCTION

Algoraves give space for the artistic consideration of our algorithm- and data-rich culture [1]. Not all algoravethmic performances involve live coding [2] as control interface, but many do, with the most popular systems including Tidal [3] and SuperCollider [4]. The author uses SuperCollider in their live laptop practice, with the latest iteration of a live coding mixer first detailed sixteen years ago and used in hundreds of concerts since (red window to the side in Figure 1) [5].

Livedog, inc. is a solo performance project to continue a vein of more theatrical live coding initiated by the duo Wrongheaded (active 2009-2012, with Matthew Yee-King). Wrongheaded delighted in different themes for each concert, from 'Algorithmic dissection' (of a teddy bear in a converted operating theatre), to an algorithmic séance (channeling Alan Turing), to *The Gospel According to Wrongheaded* (with Markov chain rewriting of the Bible and other irreverence [1]). The band explored algorithmic choreography to control their bodies as well as resultant music through code.

The two 'pieces' discussed here are necessarily those most suited to a sonification conference, and founded in mappings from scientific data and mathematical models to music. The two works should not be taken as fixed in any sense, but improvisation frameworks within which multiple algorithms can be dropped in and out for different occasions; the algorithms presented here are representative resources for such performance.

2. *HARD SCIENCE*

Hard Science is chosen as title in playful contrast to music's typical modern placement amongst the arts, gently goading the science envy of music psychologists. The harder sciences, themselves on a continuum from physics through chemistry to biology, are the source of data and mathematical models for sonification, alongside a heady application of physics in a quantum computer.

From physics, a Schwarzchild solution (1915) to motion under general relativity is explored.[2] A synthesizer instantiating the second order dynamical equations with a Euler finite difference solver has been built with Web Audio API to run as a web browser app.

Initially devised for the Newcastle Chemical Algorave organized by Shelly Knotts and Agnieszka Bronowska, the Periodic Table Sequencer viewable in Figure 1 sources element data, and provides a visual depiction of the current position within the table. Atomic numbers start at 1, whereas normal indexing in most computer programming languages including SuperCollider starts at 0 (MATLAB with its matrix indexing and Lua provide exceptions), so care has to be taken in accessing the elements.

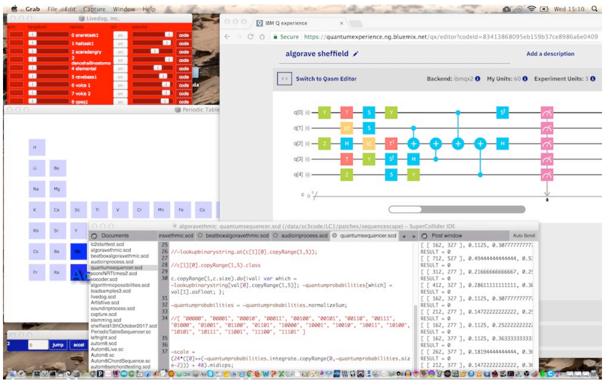

Figure 1 Live performance interface, quantum computer live coding web interface, and periodic table sequencer.

Auditory modeling connects computer music and biology. Auditory filterbanks, and models of the physiology of an inner hair cells, are utilized as signal processing elements in unit generator graphs for sound synthesis and effects processing. Simulation of the signal at a certain point in the auditory system becomes a creative effect, including through feedback of output as a new auditory signal input to recursively analyse [6].

[1] https://vimeo.com/195936508

[2] https://en.wikipedia.org/wiki/File:Newton_versus_Schwarzschild_trajectories.gif

IBM's publicly accessible 5 qubit quantum computer[1] has been used to generate sequencer data in a number of previous performances. A program can be live coded for the device as a layout of quantum logic gates on five tracks corresponding to the five qubits (IBM themselves noted the similarity to a musical score stave; see example within Figure 1). The measured output of a run of the program is a probability distribution over $2^5 = 32$ states, downloadable as a csv file that can be opened in SuperCollider. This data is mapped through to a sequencer, either as a succession of parameter control values, or as probabilities for triggers over 32 steps. Though not the first quantum computer music composed [7] this was certainly the first live coded.

3. A HISTORY OF MATHEMATICS

There is a deep and rich history to mathematics, studied by historians of science, and many aspects of mathematics have surprisingly ancient precursors [8]. Interactions with music are similarly ancient [9]. The taking of a square root has an algorithm reputedly dating back to Babylonia (it is derivable through Newton's method but substantially predates it). In music, campanology (change ringing of bells) anticipated permutation chains within groups by many centuries.

Jost Bürgi in the later 16th century devised an algorithm to create high precision sine tables for astronomy; it simultaneously refines an array of estimates of the sine values spanning between 0 and 0.5pi radians [10]. Bürgi's sine oscillator is created from the output of his sine tables, by piecing together four segments with appropriate sign. In practice, the Bürgi method is so fast converging, that it had to be artificially slowed down for musical purposes to allow for interesting intermediate wavetables as iteratively applied to an initial noise waveform. Figure 2 plots the sound waveform for successive wavetables created through this method, with some slowing to avoid almost instant convergence.

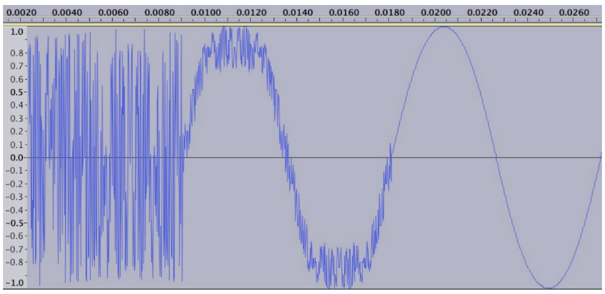

Figure 2 Three cycles of the Bürgi sine refinement method, from noise to sinusoid

Riemann's zeta function provides perhaps the most famous outstanding problem in mathematics, and is the subject of a parallel sonification paper submitted to this conference; many SuperCollider patches have been created to exploit mathematical properties of the function, and associated data on its zeroes and the prime numbers.

As a further take on the prime numbers, generalisation of the sieve of Eratosthenes is made by growing sets based on modulo relations between the current members of the set and a potential new entry. For example, in SuperCollider code, the primes up to 10000 could be tested successively:

```
a = List[];
9999.do{|i|  var number = 2+i;  var addme = true;
a.do{|j|  if (number%j == 0) {addme = false;}; };
if(addme) {a.add(number);};  };
```

The relation number%j ==0 can then be changed to new conditions such as (5*number*number+1)%j == 7 to obtain new sets.

Meanwhile, the simply stated 3x+1 problem has proven a great resource for sequence generation in live coding (iterate on value x: if even, halve, if odd, 3x+1).[2]

4. LIVE SET

For the ICAD algorave, Livedog, inc. proposes a 29 minute set, with roughly half dedicated to the work *Hard Science*, and half to *A History of Mathematics*. The boundaries of the two halves of the set are denoted by a costume change, from white lab coat, to tweed jacket and pipe.

DEMO VIDEOS:

Chemistry Set (10m55s):
https://www.youtube.com/watch?v=oWKBEXJLW_c

Qusic (12m42s):
https://www.youtube.com/watch?v=yLytSatUHTs

5. REFERENCES

[1] N. Collins and A. McLean, "Algorave: live performance of algorithmic electronic dance music," Proc. of NIME, London, 2014.

[2] N. Collins, "Live Coding of Consequence", Leonardo vol. 44, no. 3., pp. 207-211, 2011.

[3] A. McLean, "Making programming languages to dance to: live coding with tidal," Proc. of the 2nd ACM SIGPLAN International Workshop on Functional art, music, modeling & design, 2014, pp. 63-70.

[4] S. Wilson, D. Cottle, and N. Collins, The SuperCollider Book, Cambridge, MA: The MIT Press, 2011.

[5] N. Collins, "Generative Music and Laptop Performance," Contemporary Music Review, vol. 22, no. 4, pp. 67-79, 2003.

[6] R. F. Lyon, Human and machine hearing. Cambridge: Cambridge University Press, 2017.

[7] Edward Braund, and Eduardo R. Miranda, "Unconventional computing in music," In Proc. of the 9th Conference on Interdisciplinary Musicology, Berlin, Germany, 2014.

[8] Carl B. Boyer and Uta C. Merzbach, A History of Mathematics, Hoboken, NJ: John Wiley and Sons, 2011.

[9] N. Collins, "Origins of Algorithmic Thinking in Music," book chapter in Alex McLean and Roger Dean (eds.), The Oxford Handbook of Algorithmic Composition. New York: Oxford University Press, 2018.

[10] Menso Folkerts, Dieter Launert and Andreas Thom, "Jost Bürgi's method for calculating sines," Historia Mathematica, vol. 43, no. 2, pp. 133-147, 2016.

[1] https://quantumexperience.ng.bluemix.net

[2] A fantastic source for novel ideas for sequence data is the Online Encyclopedia of Integer Sequences https://oeis.org/)