Neurohedron: A Nonlinear Sequencer Interface

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ABSTRACT
The Neurohedron is a multi-modal interface for a nonlinear sequencer software model, embodied physically in a dodecahedron. The faces of the dodecahedron are both inputs and outputs, allowing the device to visualize the activity of the software model as well as convey input to it. The software model maps MIDI notes to the faces of the device, and defines and controls the behavior of the sequencer's progression around its surface, resulting in a unique instrument for computer-based performance and composition.

Keywords
Interface, Controller, Live Performance, Neural Network, Sequencer, Human Computer Interaction.

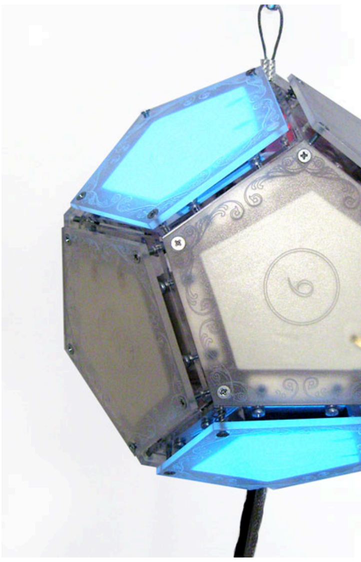

Fig. 1: The Neurohedron Hardware Interface

1. INTRODUCTION & BACKGROUND
Traditional music sequencers are designed fundamentally around predictability and repetition, which are powerful elements that have contributed to their ubiquity in contemporary composition and performance. Modern approaches to algorithmic composition, in contrast, heavily involve unpredictability and randomness that may be tamed and manipulated by the composer, resulting in a nonlinear compositional and performative process.

The Neurohedron is a novel musical instrument and modal software controller that I conceived of as a nonlinear sequencer. The simplest traditional sequencers may employ eight or sixteen steps that return to the first step after reaching the last step. The Neurohedron, however, is a three dimensional sequencer with twelve steps arranged as a dodecahedron. With this structure, there is no clear or de facto path that the progression from one step to the next may take, unlike the linear and prescribed nature of a traditional sequencer.

Conceptually, this design originated out of a desire to build what is essentially a spherical step-sequencer, one in which the path of the sequence can change based on a variety of models, as opposed to the "circle" of a traditional sequencer. In this sense, the Neurohedron software model can be seen as an "aleatoric sequencer" as well as a form of Markov chain, in which the result of each time-state depends on the results of the previous time-states.

As a mathematical graph [1], the shape of a dodecahedron has some interesting and useful properties. Each face (also herein referred to as a node) has five neighbors and thus five connections (edges) to other faces, but the shape also supports a Hamiltonian cycle, in which each node is traversed exactly once and the path returns to where it started from. If each node is assigned a MIDI note in a chromatic scale, a Hamiltonian cycle

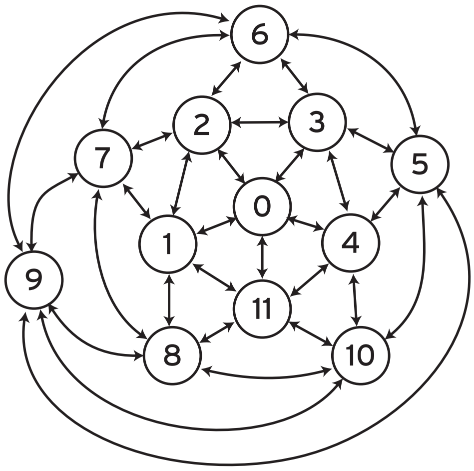

Fig. 2: Dodecahedron Graph Representation

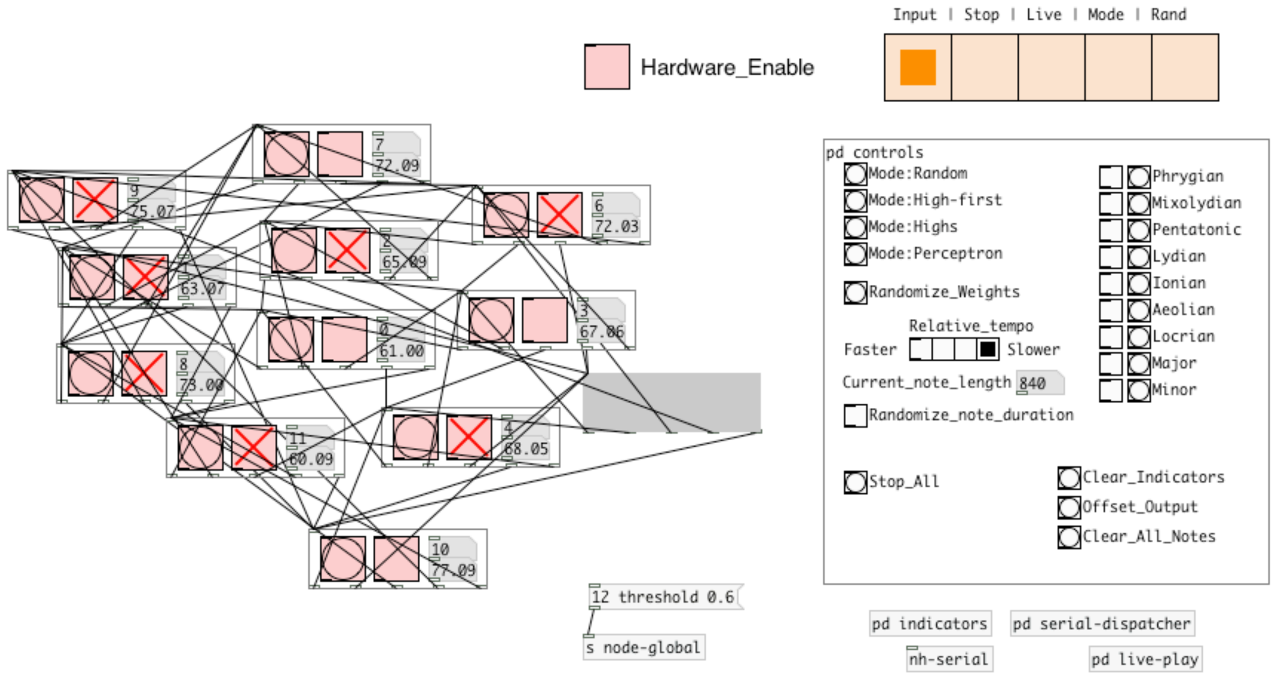

Fig. 3: Neurohedron Software GUI

around the Neurohedron will play each and every note in order from lowest to highest, and return to the lowest note again. This property was a desirable design consideration for the sake of maximum flexibility and musical range.

2. IMPLEMENTATION

The Neurohedron is a controller for a software model that is integral to the design and concept of the hardware. Although useful alone, the software is most effective in conjunction with the physical dodecahedron, since the 2-dimensional graph representation is more difficult to read and understand than the actual surface of the object.

2.1 Software

The Neurohedron software, implemented entirely in Puredata, manages the network model, serial I/O and MIDI I/O.

In the interest of developing a nonlinear sequencer, I designed a 12-node recurrent neural network, in which each face is connected in a graph to the 5 faces adjacent to it. Each of the edges between these faces is then weighted between -1 and 1, and the progression of stimuli from one face to another follows one of several computational models:

- Random Walk: An activated node progresses to one of its five neighbors randomly.
- Highest Weighted Edge: The highest weighted edge or edges triggers the next node
- Perceptron Model [2]: The sum of all weights inputted into the node must surpass a threshold before the node activates.

Each node (face) in the network is then mapped to a MIDI note as defined by an array of musical modes. Thus, a sequence on the Neurohedron sends patterns of MIDI notes to a synthesizer.

The interface is multi-modal, meaning that there are 5 states the interface can be in that determine what it does:

- Input: Pressing a face triggers an input stimulus to the neural network at that node
- Stop: Holding a face down stops any stimuli that encounter that node
- Live-play: Sends MIDI notes pursuant to that face's current mode-mapping
- (Musical) Mode: Changes the mode-mapping of the network
- Randomize: Randomizes all of the neural network's weights

These modes are selectable via a wired foot-switch the plugs into the device, enabling convenient live composition with zero direct interaction with the computer.

2.2 Learning & Sequencing

One unique aspect of the neural network model in the role of a sequencer is its relative unpredictability, but another is its ability to dynamically change the weights of edges between neurons and thus change the sequence. I have experimented with the following approaches to weight modification, all of which are conducted in realtime as the network is running.

- "Subtractive Sequencing": Edges are initialized with high, random weights and the user holds down faces to manually inhibit connections. High weights are likely to activate all adjacent neurons, resulting in a kind of "musical seizure" in which every node, and thus every assigned MIDI note, is being activated. As this is generally undesirable, inhibiting connections between neurons by lowering weights will gradually result in only certain neurons becoming activated in certain patterns. I call this "subtractive sequencing," as the composer "carves out" a desired sequence from what begins as noise.
- Path-seeking or "additive sequencing": Specifying a start-point and end-point causes the weights between those nodes to be increased, and weights of undesirable edges to be decreased. In this way, the composer can begin to define desirable sequences in chunks, as well as switch to the subtractive mode to "erode" those sequences.

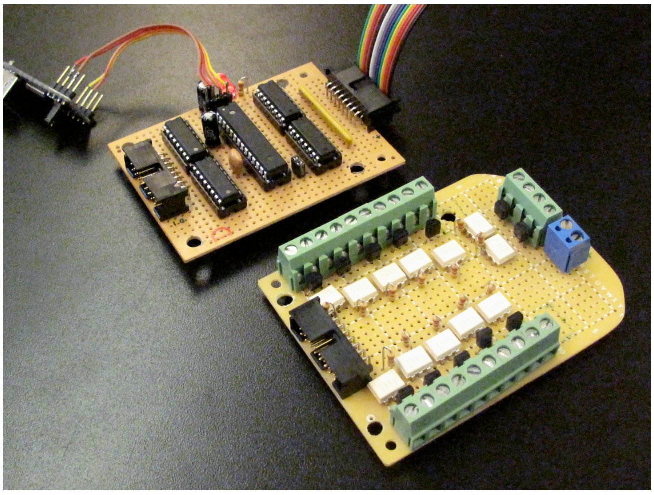

Fig. 4: Logic Board (left) and AC Switching Array (right)

- Supervised learning: The most truly "neural" approach, supervised learning uses Hebb's rule to determine a sequence by adjusting weights in response to the user's feedback. Weights are initialized randomly and a random initial stimulus is applied. After every iteration of the sequence, the user (or another, automated software module) decides whether he or she "likes" the sequence. Gradually, the sequence will adapt to fit the most "desirable" pattern. This method is best suited for an automated installation-like setting, as it evolves over a longer period of time.

2.3 Hardware

The Neurohedron is, physically, an 18" diameter plexiglas dodecahedron with all electronics closeted inside it. Each face on the device is both a momentary touch-switch that sends input triggers to software as well as an electroluminescent panel that indicates feedback from the software.

The Neurohedron's hardware consists of:

- Plexi & aluminum chassis
- Laser-etched faces
  - Momentary switches
  - EL panels
- Logic Board
  - ATMEGA328PU Microcontroller
  - 2x 8-bit shift-in registers
  - 2x 8-bit shift-out registers
  - FTDI USB Interface
- AC Switching array
  - 12x Optoisolated triac & low-current triac pairs
- Wired Connections
  - Foot-switch
  - USB
  - EL power from AC inverter

The electroluminescent panels [3] are attached behind the user-facing plexi faces and in front of the momentary switches, and insulated. These EL panels operate on 150-300VAC at a nominal 650hz, and thus require an independent switching array that is optoisolated from the rest of the 5V logic circuitry, using pairs of low-current triacs. The pairs of 8-bit shift registers accommodate 16 channels of I/O, 12 for the faces of the device and one additional input for the foot-switch.

The registers communicate with the Atmega microcontroller, which communicates over USB serial to the host computer at 38,400 baud. This configuration results in very low latency with very high reliability.

3. EXPERIENCE & FUTURE CONSIDERATIONS

The Neurohedron debuted at ITP's 2009 NIME concert, and I have since utilized the device in several different performances in different contexts. It has proven to be not only a useful and unique compositional tool, but a focus of interest and wonder as a physical, illuminated and mysterious object.

One of my primary design goals with the Neurohedron was to eliminate direct computer interaction, so that the performance consists solely of interaction with the instrument, and this has been successfully achieved. Additionally, I was interested in developing a platform that requires practice and allows for a degree of virtuosity; this, too, I believe I have accomplished. The operation of the device is intuitive to the extent that pressing one of the faces is likely to have an immediate effect, but the nature of that effect and its causes and ramifications is obscured, and takes practice to develop desired results. Furthermore, as the interface is integrally time-based, a sense of rhythm is required if one is to achieve synchronized sequences, and in my experience definitely allows for the development of a proficiency exclusive to this instrument.

In the future, I would first like to improve the input method, ideally to a conductive-based approach rather than a mechanical switch approach, which requires a good deal of extra structural engineering. I would also like to improve the design of the logic board and switching array and have them professionally printed.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

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