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MUS 221
Final Project

Quantum Noise

Quantum noise is a piece of music which is in many ways as scientific as the name suggests. It is an experiment in response to a hypothesis, that physical systems have a sort of musicality inherent in the related constants shifting and responding to one another. And what better system to use than the one I work on for research? It is a system of three, two-level atoms which can exchange energy with one another, absorb energy from a driving field (such as a laser), and emit energy to the environment through spontaneous emission. The method used to probe this system is called the quantum trajectory method. It involves simulating the system several hundred times, where each time uses random numbers to simulate spontaneous emission. This seemed a good system to use, as the entanglement measures I have been studying are certainly related but not all equal, and the measures of nonlocality have a similar relation to each other and the entanglement. In addition, the random jumps at first glance seem to lend themselves to interval jumps in traditional music.

The initial idea was to use the trajectories to generate a series of notes using music theory and Abjad with Lilypond, and then from there pick and choose several from which to make a composition. This idea was thrown out fairly quickly, however, as it seemed more interesting to use the physical parameters to modify the timbre of the sound itself in addition to the pitch and dynamics. As a result, rather than using the physical quantities to define the musical theory, they were used to define the parameters of each note, which in the case of this program was a sum of sine waves. The following lists the equivalencies between the notes and the system:

- Pitch- Nonlocality, as defined by Svetlinchny's operator
- Amplitude- Nonlocality, as defined by Mermin's operator
- ASDR Envelope- The entanglement of the three bipartite splits
- Duration- Three-Tangle, a measure of genuine three party entanglement
- Timbre- the probability of finding the system in one of eight possible states. The timbre was built up of the base pitch and the first eight whole number multiples, with the relative amplitude of each wave based on the aforementioned probabilities.

The data was read from files produced during research, and the sound was generated using NumPy's sine function and SciPy's wavefile process. The range of pitches, durations, timbres, and amplitudes varied over the course of production, but the final realization used the C major scale as the base notes, a series of amplitudes chosen to be quiet enough to layer, and durations based on either quarter notes, triplet values, or short values such as eighth and sixteenth notes. All this was to achieve some level of musicality, as the hope of the project was to produce a sound which is 'musical,' and to make production and layering of various sounds easier and avoid dephasing. Once individual sounds were produced, they were sampled and a smattering of the most interesting were combined in Audacity, using the naturally varying lengths of each file to allow for different elements to begin at different times.

After some trial and error, the final form of the song was decided upon and then inverted, as it built up better and had more of a 'musical' sound. In the end, the experiment was a mild success, in the sense of producing something instantly recognizable as music. Individual sound files have musical components, but on also contain sections which are too repetitive and random to be completely 'musical,' as they do not mimic well compositions made with less a focus on process.

The piece as a whole, however, does exhibit musical characteristics often enough, and has a certain, though not typical, musical nature. The background drone, the high pitches, the ebb and flow of dynamical content, and the motivic material: all of this implies musicality. And, other than being a different way to appreciate the quantum world underlying our very classical one, it is an interesting example of a sound which causes one to wonder, 'what is music?' It is in some sense an exercise for the listener to pick out and determine what, if any, of the piece is musical and what is random noise, as too much implies musicality, but it has less of the intentionality of a traditional piece, relying more heavily on formulaic evolution.