

# Cognitive Music Modelling: An Information Dynamics Approach

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**Abstract**—People take in information when perceiving music. With it they continually build predictive models of what is going to happen. There is a relationship between information measures and how we perceive music. An information theoretic approach to music cognition is thus a fruitful avenue of research.

## I. INFORMATION THEORY AND PREDICTION

Bayesian probability and modelling the building of predictions

### A. Link to music

Music as a temporal pattern. Meyer, Narmour. Music unfolding in time. How listeners see different kinds of predictability in musical patterns..

## II. INFORMATION DYNAMICS APPROACH

*Re-iterate core hypothesis*

### A. models/parameters/observations

The grouping of elements into past, present and future..

### B. Information measures

Predictive information rate as a measure of structure Crutchfield papers, anatomy of abit

### C. Case of this approach being good at modelling music cognition

Inverted U

## III. INFORMATION DYNAMICS IN ANALYSIS

refer to the work with the analysis of minimalist pieces

### A. Sound Categorisation

Using Information Dynamics it is possible to segment music. From there we can then use this to search large data sets. Determine musical structure for the purpose of playlist navigation and search. (Peter)

### B. Beat Tracking

Bayesian belief can be used to predict when things happen (as oppose to just what happens). Information Dynamics of?

## IV. INFORMATION DYNAMICS AS DESIGN TOOL

In addition to applying Information Dynamics to analysis, it is also possible use this approach in design, such as the composition of musical materials. By providing a framework for linking information theoretic measures to the control of generative processes, it becomes possible to steer the output of these processes to match a criteria defined by these measures. For instance outputs of a stochastic musical process could be filtered to match constraints defined by a set of information theoretic measures.

The use of stochastic processes for the generation of musical material has been widespread for decades – Iannis Xenakis applied probabilistic mathematical models to the creation of musical materials, including to the formulation of a theory of Markovian Stochastic Music. However we can use information dynamics measures to explore and interface with such processes at the high and abstract level of expectation, randomness and predictability. The Melody Triangle is such a system.

### A. The Melody Triangle

The Melody Triangle is an exploratory interface for the discovery of melodic content, where the input – positions within a triangle – directly map to information theoretic measures associated with the output. The measures are the entropy rate, redundancy and predictive information rate of the random process used to generate the sequence of notes. These are all related to the predictability of the the sequence and as such address the notions of expectation and surprise in the perception of music.*self-plagiarised*

Before the Melody Triangle can used, it has to be populated with possible parameter values for the melody generators. These are then plotted in a 3d statistical space of redundancy, entropy rate and predictive information rate. In our case we generated thousands of transition matrixes, representing first-order Markov chains, by a random sampling method. In figure x we see a representation of how these matrixes are distributed in the 3d statistical space; each one of these points corresponds to a transition matrix.*self-plagiarised*

When we look at the distribution of transition matrixes plotted in this space, we see that it forms an arch shape that is fairly thin. It thus becomes a reasonable approximation to pretend that it is just a sheet in two dimensions; and so

we stretch out this curved arc into a flat triangle. It is this triangular sheet that is our Melody Triangle and forms the interface by which the system is controlled. *self-plagiarised*

When the Melody Triangle is used, regardless of whether it is as a screen based system, or as an interactive installation, it involves a mapping to this statistical space. When the user, through the interface, selects a position within the triangle, the corresponding transition matrix is returned. Figure x shows how the triangle maps to different measures of redundancy, entropy rate and predictive information rate. *self-plagiarised*

Each corner corresponds to three different extremes of predictability and unpredictability, which could be loosely characterised as periodicity, noise and repetition. Melodies from the noise corner have no discernible pattern; they have high entropy rate, low predictive information rate and low redundancy. These melodies are essentially totally random. A melody along the periodicity to repetition edge are all deterministic loops that get shorter as we approach the repetition corner, until it becomes just one repeating note. It is the areas in between the extremes that provide the more interesting melodies. That is, those that have some level of unpredictability, but are not completely random. Or, conversely, that are predictable, but not entirely so. This triangular space allows for an intuitive exploration of expectation and surprise in temporal sequences based on a simple model of how one might guess the next event given the previous one. *self-plagiarised*

Any number of interfaces could be developed for the Melody Triangle. We have developed two; a standard screen based interface where a user moves tokens with a mouse in and around a triangle on screen, and a multi-user interactive installation where a Kinect camera tracks individuals in a space and maps their positions in the space to the triangle. Each visitor would generate a melody, and could collaborate with their co-visitors to generate musical textures – a playful yet informative way to explore expectation and surprise in music.

As a screen based interface the Melody Triangle can serve as composition tool. A triangle is drawn on the screen, screen space thus mapped to the statistical space of the Melody Triangle. A number of round tokens, each representing a melody can be dragged in and around the triangle. When a token is dragged into the triangle, the system will start generating the sequence of notes with statistical properties that correspond to its position in the triangle. *self-plagiarised*

In this mode, the Melody Triangle can be used as a kind of composition assistant for the generation of interesting musical textures and melodies. However unlike other computer aided composition tools or programming environments, here the composer engages with music on the high and abstract level of expectation, randomness and predictability. *self-plagiarised*

Additionally the Melody Triangle serves as an effective tool for experimental investigations into musical preference and their relationship to the information dynamics models.

## V. MUSICAL PREFERENCE AND INFORMATION DYNAMICS

We carried out a preliminary study that sought to identify any correlation between aesthetic preference and the information theoretical measures of the Melody Triangle. In this study participants were asked to use the screen based interface but it was simplified so that all they could do was move tokens around. To help discount visual biases, the axes of the triangle would be randomly rearranged for each participant. *self-plagiarised*

The study was divided in to two parts, the first investigated musical preference with respect to single melodies at different tempos. In the second part of the study, a back- ground melody is playing and the participants are asked to find a second melody that works well with the background melody. For each participant this was done four times, each with a different background melody from four different areas of the Melody Triangle. For all parts of the study the participants were asked to mark, by pressing the space bar, whenever they liked what they were hearing. *self-plagiarised*

*todo - results*

## VI. INFORMATION DYNAMICS AS EVALUATIVE FEEDBACK MECHANISM

*todo - code the info dyn evaluator :)*

It is possible to use information dynamics measures to develop a kind of ‘critic’ that would evaluate a stream of symbols. For instance we could develop a system to notify us if a stream of symbols is too boring, either because they are too repetitive or too chaotic. This could be used to evaluate both pre-composed streams of symbols, or could even be used to provide real-time feedback in an improvisatory setup.

*comparable system* Gordon Pask’s Musicolor (1953) applied a similar notion of boredom in its design. The Musicolor would react to audio input through a microphone by flashing coloured lights. Rather than a direct mapping of sound to light, Pask designed the device to be a partner to a performing musician. It would adapt its lighting pattern based on the rhythms and frequencies it would hear, quickly ‘learning’ to flash in time with the music. However Pask endowed the device with the ability to ‘be bored’; if the rhythmic and frequency content of the input remained the same for too long it would listen for other rhythms and frequencies, only lighting when it heard these. As the Musicolor would ‘get bored’, the musician would have to change and vary their playing, eliciting new and unexpected outputs in trying to keep the Musicolor interested.

In a similar vain, our *Information Dynamics Critic*(name?) allows for an evaluative measure of an input stream, however containing a more sophisticated notion of boredom that ...

## VII. CONCLUSION