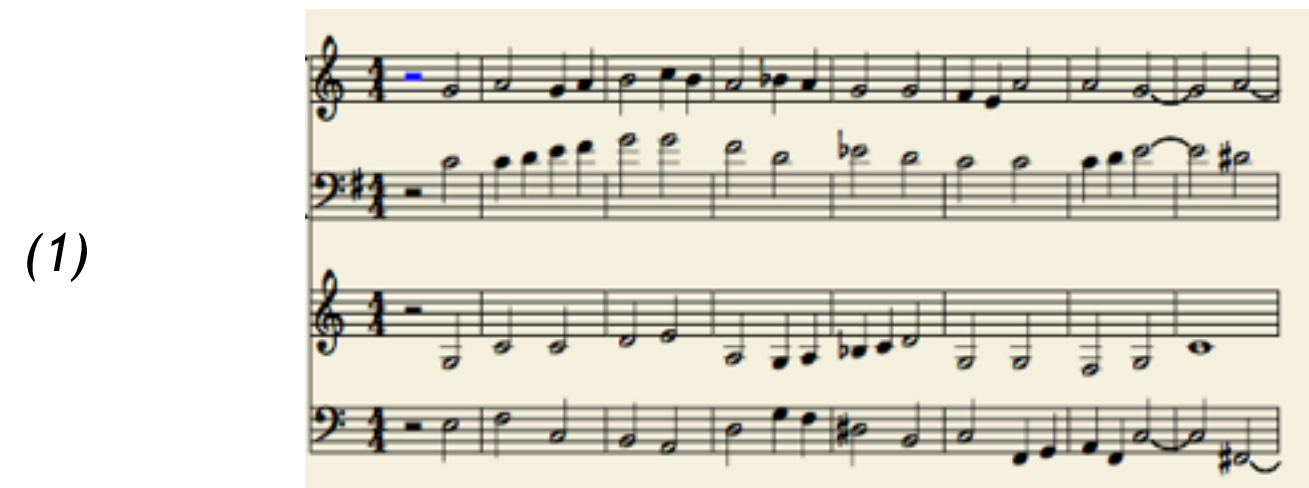


# COMPARING ARTIFICIAL INTELLIGENCE MUSIC AND HUMAN MUSIC: A CASE STUDY OF PROF. DAVID COPE'S EMMY SYSTEM

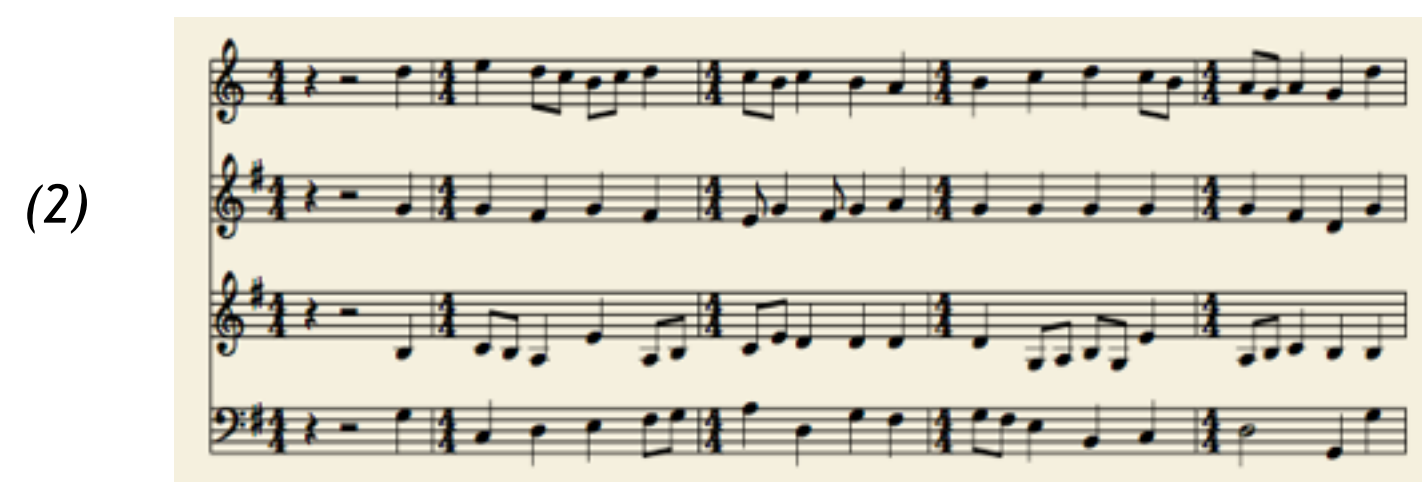
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## Prelude: Introduction

One of the music here is composed by a well-known algorithmic composition system: EMMY, developed by Prof. David Cope [1]. The other one is the actual J.S.Bach's music.



It's hard to differentiate between them, but we found that calculating Shannon entropy is actually helpful!



Question of the day: Can you tell which one is composed by J.S.Bach and which one is composed by the computer program? And why? (The answer is at the last block of this poster)

## Andante: Introduction to Information Measures

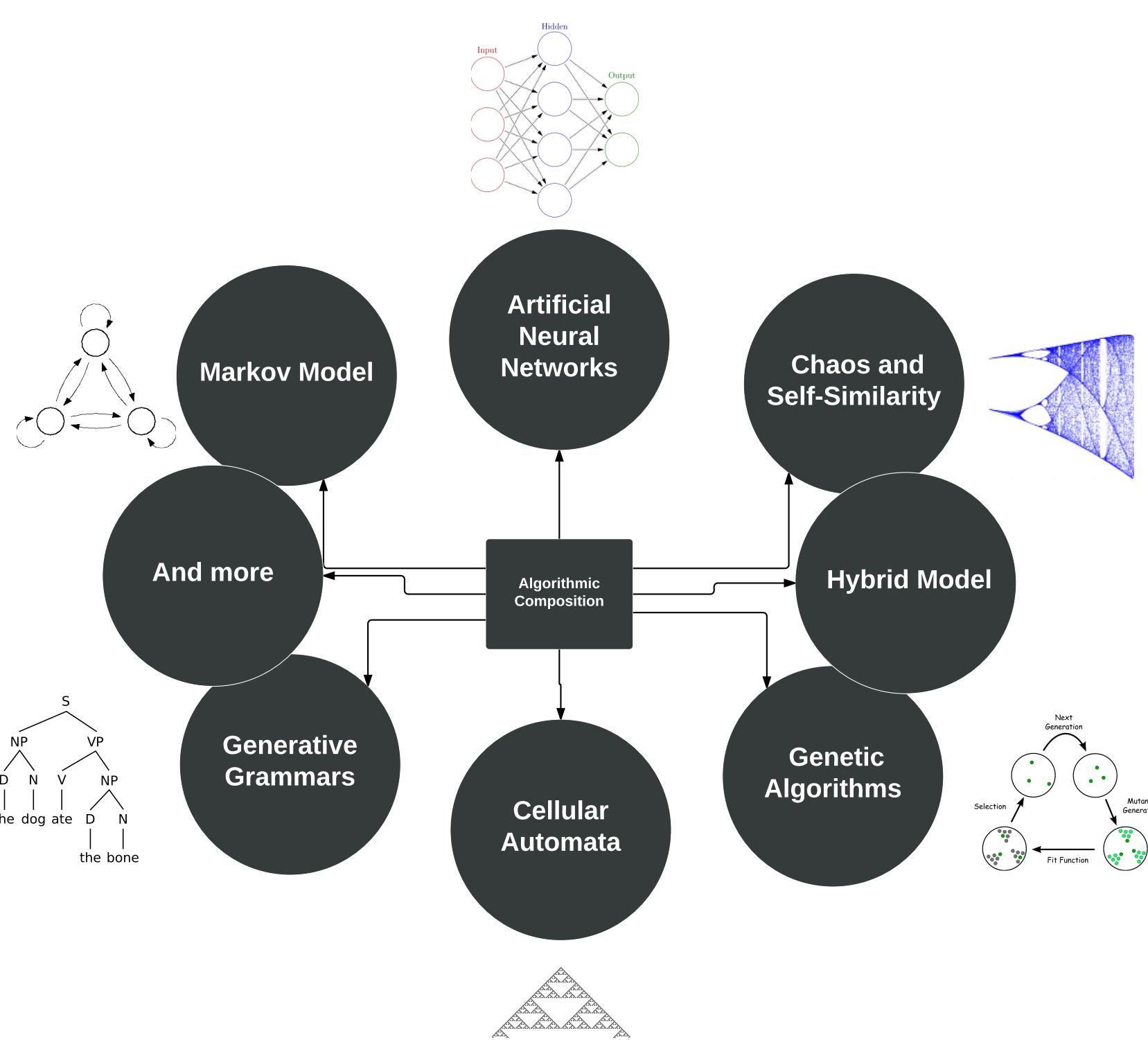
Mathematical definitions:

The Shannon entropy:  $H(X) = \mathbb{E}_X[I(x)] = -\sum_{x \in X} p(x) \log p(x)$ .

Information content:  $I(\omega_n) = \log\left(\frac{1}{P(\omega_n)}\right) = -\log(P(\omega_n))$

- For uniform distributions, the entropy increase with the number of outcomes. For example, the entropy of a monotone sequence is lower than the entropy of scales of any kind.
- The entropy is lower when there is reduced uncertainty. For example, tonal music has smaller entropy than atonal music, since there are more frequent notes in the tonal, and this give us a smaller term in the definition of entropy.
- The entropy remains the same when there is a repeat. For example, if we concatenate 2 bars of the same music together, the 4 bars music will have the same entropy as the 2 bars music.

## Segue: Introduction to Algorithmic Composition



Algorithmic composition can found its history back to around the 1990s. There has been many systems designed to simulate the music creativity via mathematical models, knowledge-based systems, evolutionary methods, etc. And those methods have been applied to different genres and purposes of music creation: classical, jazzy, improvisational, modernism, atonal music, etc. For the data we are using in this paper:

- The music are generated in J.S.Bach's chorales' style by the Emmy system [1]
- The Emmy system is well-known in the community of algorithmic composition and has been there for a history of years.
- Emmy's source code is available online but not well documented. So we will not dive into the details of the algorithm but just analyse the pieces the algorithms have created.

## Allegro: Entropy comparison

Using the definition of Shannon entropy, we calculate the value for 100 EMMY's and Bach's chorales. The probability of a music note (pitch and duration pair) is calculated using:  $\text{Count}(\text{note})/\text{Length}(\text{piece})$

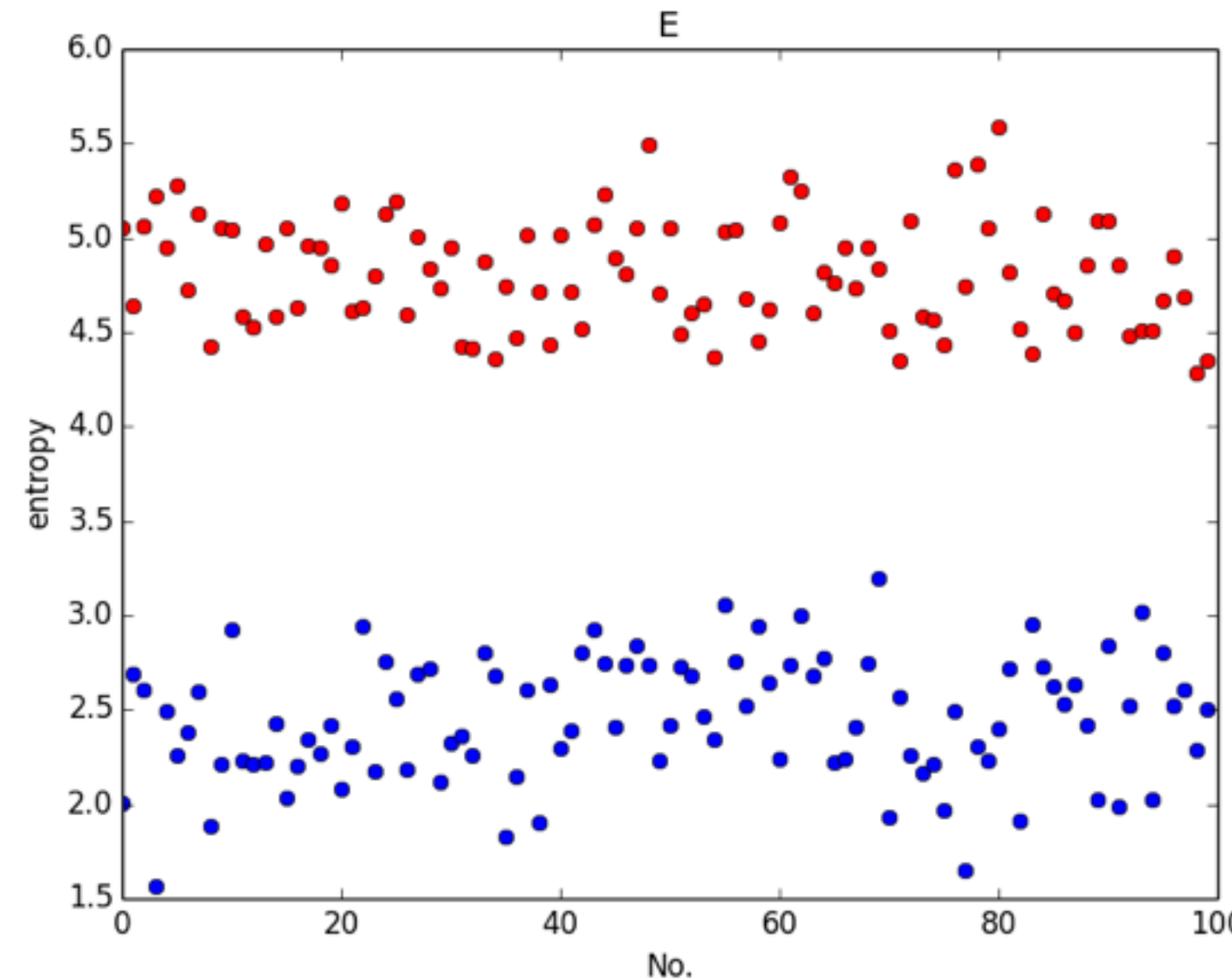


Figure 1: Entropy of pitch and duration pair. The x axis is the No. of pieces: No. 510-610 in Emmy's music and No. 110-210 in Humdrum numbering of Bach's chorales. For each x value, that is, for each piece, we have the entropy of the whole piece plotted on the y axis. Red dots indicate the AI music and blue dots for real Bach's music.

We can see that:

- The AI music and human music are separate: the entropy of music is a natural classifier of Emmy's chorales and Bach's chorales. There are underlying intrinsic unnaturalness of the Emmy's Bach chorales generating algorithm.
- The actual Bach's chorales have lower entropy and EMMY's chorales have higher entropy. From the properties of entropy, we can infer that this is because Emmy's pieces are lack of either some prominent notes or repeated patterns.

## Scherzo: Entropy window comparison

From this section onwards, we are only showing selected figures due to space limit. More results can be found in the paper and via email requests.

We lose lots of local information by summarising each music into one entropy value. We therefore propose two extended tools based on entropy: the entropy profile and the entropy window.

We first introduce the entropy window: calculated by taking chunks of equal length from the music and calculate the entropy on the chunks.

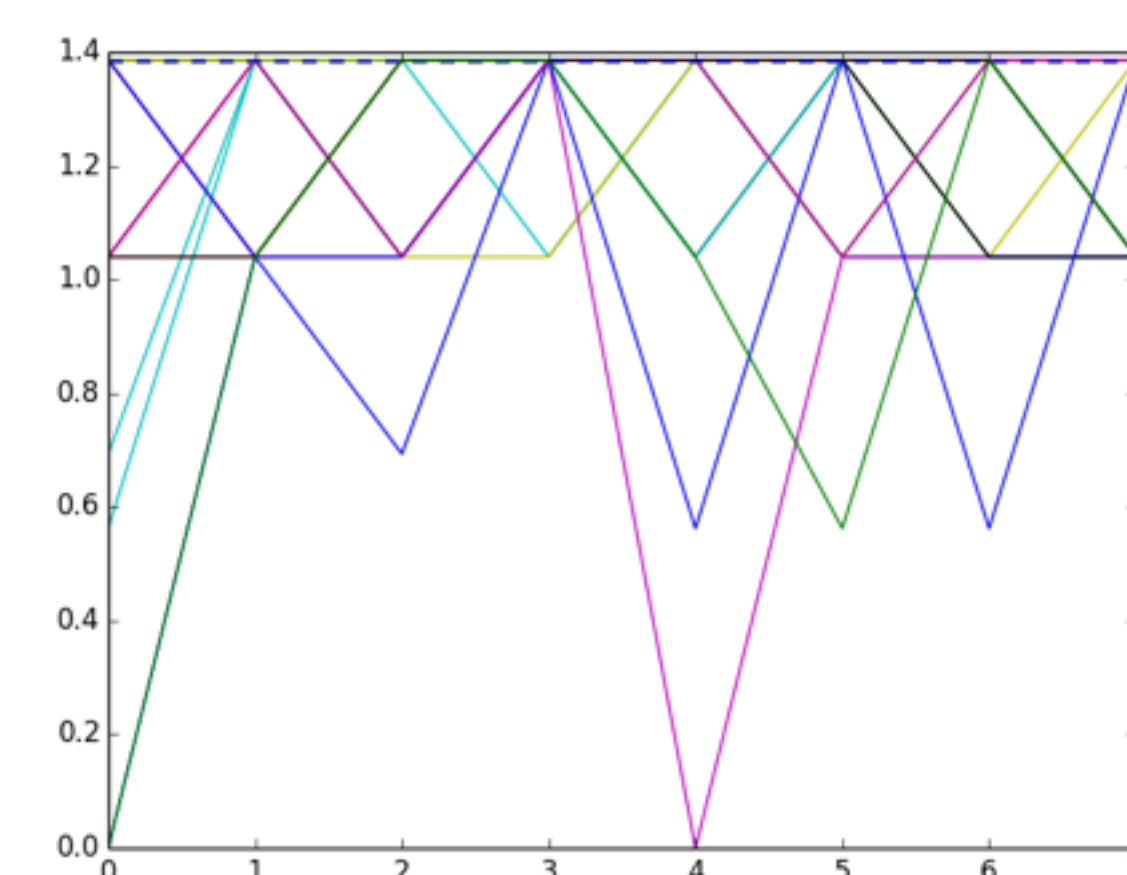


Figure 2: Entropy window of pitch and duration pair. The AI music and human music have different patterns, with the AI music are always reaching their maximum. The direction of x-axis is the time evolution in music, and the unit of x-axis is the window length, which is 4 in this figure since we have most of the pieces in the time signature of 4/4. The y-axis indicates the entropy. The dotted lines are entropy profile from AI music and the solid lines are from human music.

The local properties of entropy without long memory of the piece is still problematic!

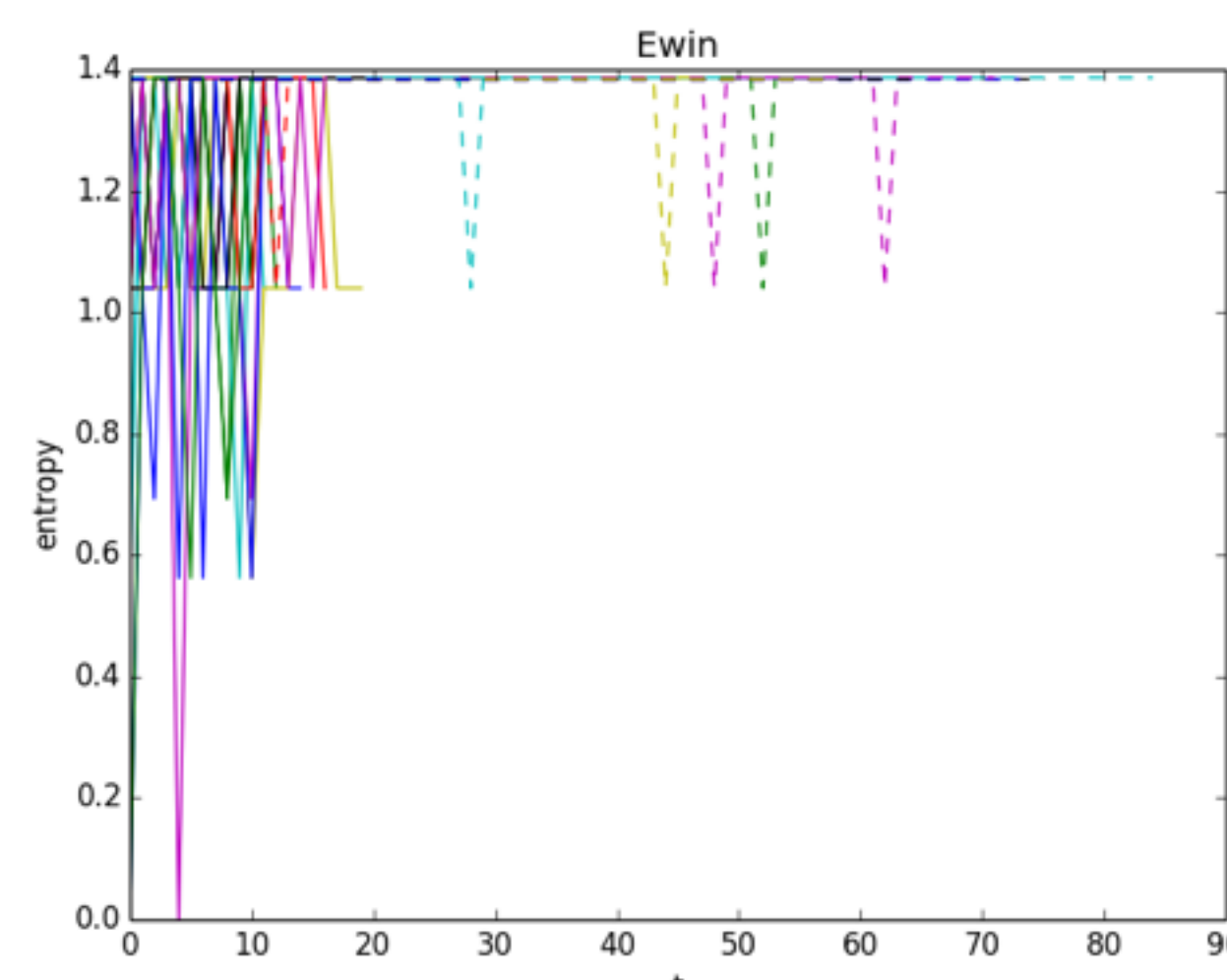


Figure 3: Entropy window of pitch and duration pair. Whole piece displaying. The long dotted line and short solid line is due to the different length of different pieces. We plot only the first few windows and profile time in other figures also because of this. The specifics of the figure are the same with Figure 2.

## Variation: Entropy profile comparison

As we mentioned in the last section, this is another tool that we designed to look at the temporal evolution of the music entropy. The difference with entropy window is that, instead of just windowing, we take chunks of increasing length, with the same increment.

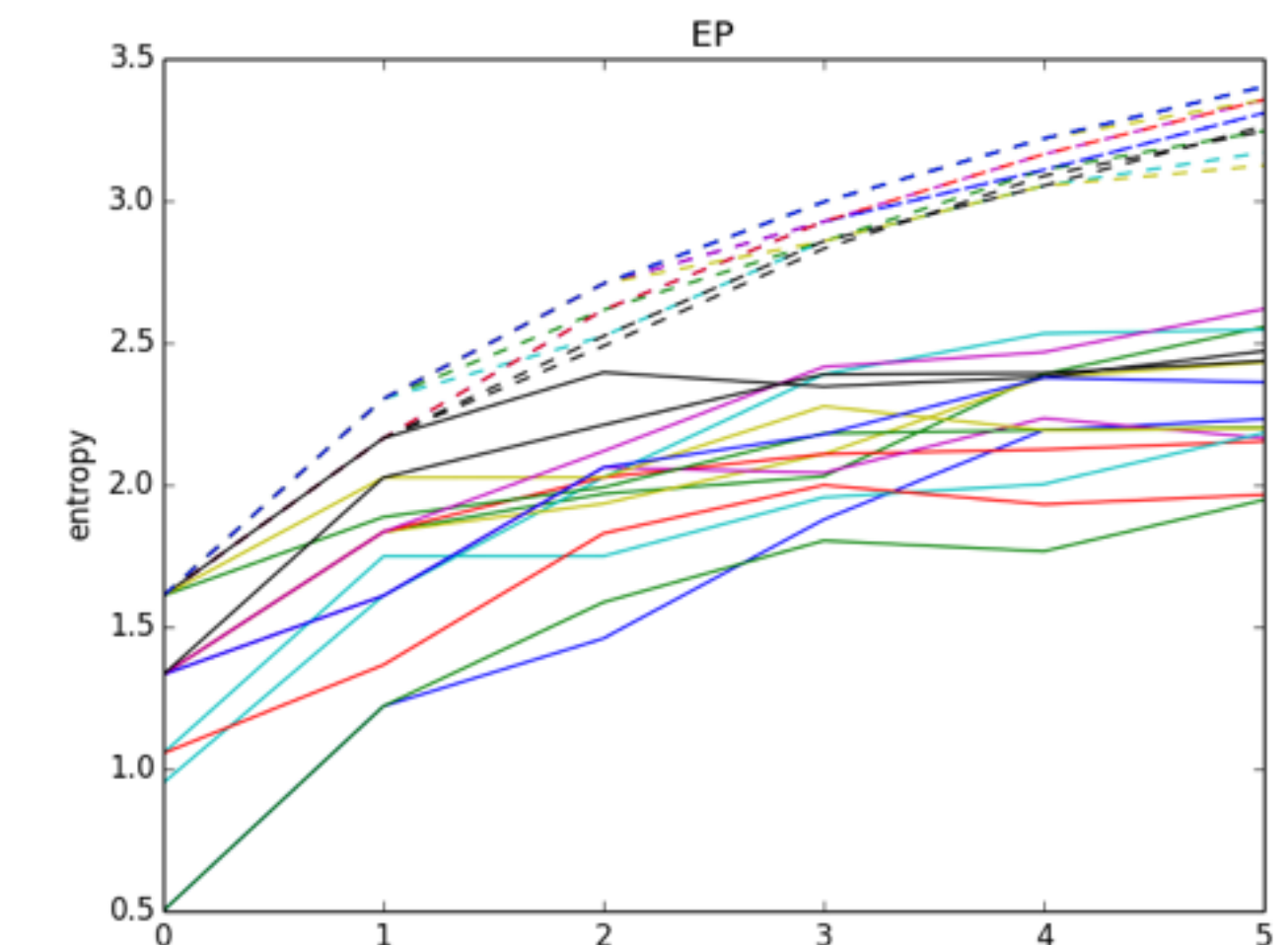


Figure 4: Entropy profile of pitch and duration pairs. Problematic because they form 2 separate groups. To further examine the problem, we plotted separately the entropy profile of pitch and duration:

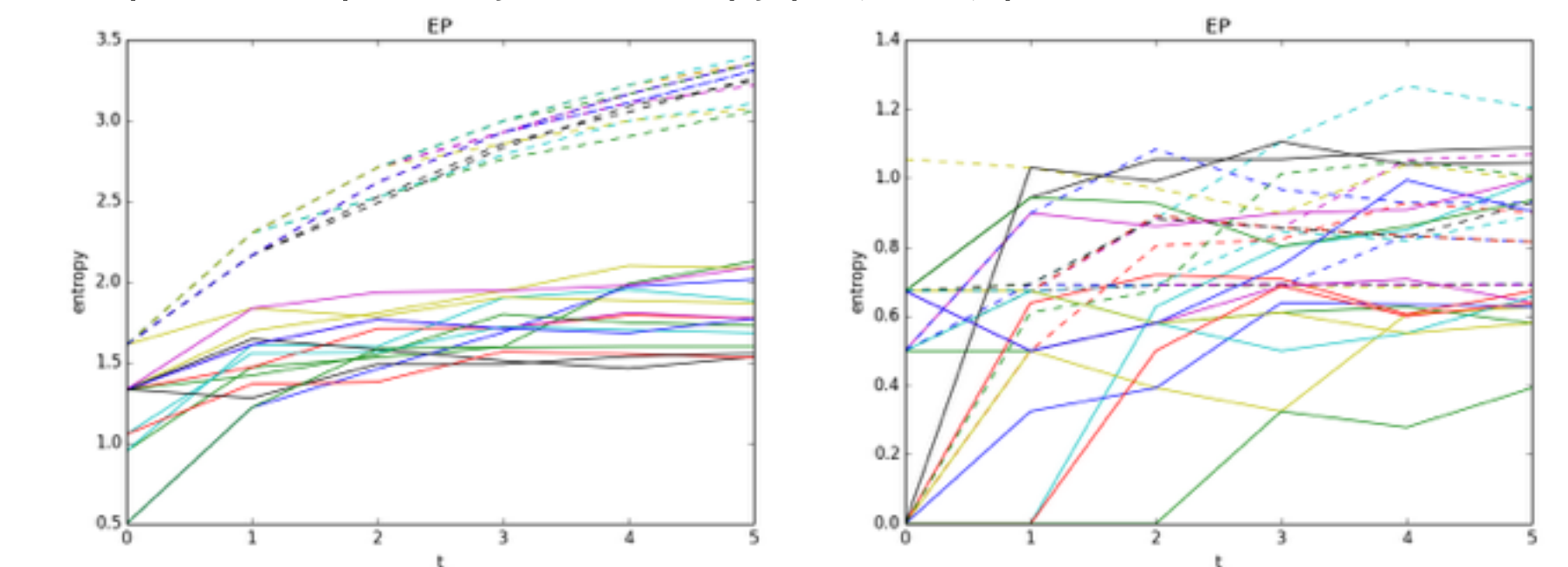


Figure 5: Entropy profile of pitch only. The AI music and human music have different patterns. The unnaturalness is showing itself in the growing smooth curves. The specifics of the figure are the same with Figure 2.

Figure 6: Entropy profile of duration. The AI music and human music are relatively well-mixed. The specifics of the figure are the same with Figure 2.

## Coda: Conclusion & Outlook

Conclusions in summary:

- We calculated entropy, entropy profile and entropy window on the human-like-AI music (Emmy's chorales in Bach's style) and human music(J.S.Bach's chorales).
- We found that the overall entropy of Emmy's pieces are in general higher than the real Bach's pieces, indicating that the AI music are less predictable and are short of repeated patterns.
- The entropy profile and entropy window verifies the conclusion given by the overall entropy and gives more details: Emmy's pieces have higher and smoother pitch entropy profiles, relatively authentic duration entropy profile, which gives clues on how to improve the composition algorithm: reduce the introduction of new pitch patterns.

Possible future works:

- Calculate the entropy, entropy profile and entropy window on more pieces.
- Develop a more general evaluation toolkit to give composers feedback on their note frequency use.
- Calculate some recommendations on how the composers can make their composition prone to a certain type of note frequency use.

## Finale: Take Home Messages

- The information measure of entropy is an important property in algorithmic composition, and further algorithm could verify and improve their system by calculating these values when generating music.
- More generally, the information theory measure can be used to compare any two compositions using the frequency of musical events. Although the order of musical events is important, the considerations without the order information has shown its potential in this study.



Answer to the question in the beginning: (1) is composed by EMMY and (2) is composed by J.S.Bach

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