The Shape of Ceòl Beag

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1 Introduction

Ceòl beag, or "light music," refers broadly to all non-piobaireachd[1] music for the Scottish Great Highland Bagpipe (GHB) [3]. Like much traditional music, ceòl beag is divided into a number of idioms, based on the tempo, time signature, feel, and purpose of the tune.[2] We propose a network theory analysis of ceòl beag tunes, aiming to better understand the often blurry distinctions between idioms, and the structure of ceòl beag tunes in general.

We begin with a quick introduction to some extant literature using networks to analyze the content of musical pieces, and present the specifics of our ceòl beag network. We then present a case study of the network for famous tune "Scotland the Brave," and compare tune-level note network statistics across idioms to better understand the differences in these tune types. We also explore the information present in idiom-level note networks, and finally the use of idiom-level note networks to generate new music for the GHB.

2 Background

We drew inspiration primarily from [2], in which the authors create a network from the music of J.S. Bach in order to study how information is embedded in his compositions. They let each node represent a note in a specific octave (e.g. C4), and connect two notes by a directed edge when those notes appear consecutively in a particular piece. Edges are

[1]Piobaireachd, or ceòl mór ("big music"), is a highly stylized form of Scottish classical music for the Great Highland Bagpipe.

[2]For example, a strathspey is a dance tune corresponding to a particular form of Celtic dance with a highly swung, clipped feel, whereas a retreat is a slower marching tune, often played to mark the end of events.

weighted by the frequency of a particular transition. Their analysis focuses on measures of entropy to quantify the information stored in a tune network, and understand the affect of human cognition on the accurate perception of these networks. While entropy quantification and perceptual analysis are outside our scope/intent of this project, we borrow heavily from the way they create their networks.

3 Methods

3.1 The Network

[1] provides a fairly large sample of the ceòl beag corpus for free download in BWW format.[3] Out of 3760 files, we found 3049 unique tunes across all idioms. We use these tunes in our network creation and analysis.

The Great Highland Bagpipe is peculiar among other musical instruments for a number of reasons. The scale of the GHB consists of only nine notes - low G, low A, B, C#, D, E, F#, high G, and high A[4] - and the "drones" of the GHB continously play A in lower octaves under any tune. This means ceòl beag can only functionally be played in a very small number of keys, and almost always in A Mixolydian or D Major. Furthermore, the GHB cannot play rests, does not have dynamic volume, and makes use of highly complex embellishments to differentiate consecutive notes. As such, rhythm becomes a incredibly central factor in any ceòl beag tune.

We leverage these oddities of GHB music to inform the creation of our network. Instead of simply encoding the pitch of a note as a node, we also encode the time duration of that note. This increases the number of possible nodes from 9 to around 81 with commonly used metric subdivisions. We choose to ignore embellishments, so nodes are connected by a directed edge when one follows another in the melody of a tune. Edges are weighted by the number of time a specific transition occurs. While [2] remove self loops from their network, they are included in ours, as repetition of the same note is central to many ceòl beag melodies (e.g. as the common "GDE" movement in the Jig idiom, figure 4).

Note that a network of this description can be created by analyzing the note transition of a

[3]BWW format is a text based file format used to typeset music for the GHB using Bagpipe Music Writer Gold software. BWW files are human readable, making them fairly easy to parse.

[4]Bagpipe sheet music often omits the sharp signs for C# and F#; we follow suit throughout the paper and refer to C# and F# as C and F respectively throughout.

Idiom	Num. Tunes	Num. Nodes	Num. Edges
4/4 March	236	81	1556
Reel	193	56	944
Jig	423	53	946

Table 1: Size info for idiom-level note networks

single piece of ceòl beag, or by analyzing any number of pieces sequentially. We focus our analysis into two main categories: understanding and comparing single tune networks, and analysing networks compiled across entire idioms.

3.2 Statistical Analysis

3.2.1 Tune Level

We generated tune-level note networks for each of 852 4/4 marches, reels, and jigs. We examined a small handful of these networks to confirm that the networks were capturing expected information about the tunes, and then computed summary statistics for each network, and across all networks in an idiom.

Unfortunately, implementing a method to directly compare note networks (e.g. Delta-Con), proved outside the scope of the project. We attempted to use graph-edit distance, but it proved too sensitive to network size to provide a useful comparison.

3.2.2 Idiom Level

We focused on three idioms - 4/4 marches, reels, and jigs - that each display distinct characteristics. 4/4 marches are traditional marching tunes, played at medium tempo; reels are quicker dance tunes, and may either be played with a "round" or "pointed" feel; jigs are also dance tunes, but quicker still and played in compound time. Table 1 shows summary information about the network for each idiom.

We analyzed structure and centrality on each network to make observations about each idiom, and computed and compared summary statistics to infer differences between idioms.

Idiom	Tunes	Strongly Connected	Avg. Clust. Coeff.	Diameter	Avg. Path Len.
4/4 March	236	205	0.0515	7.70	3.37
Reel	193	158	0.0901	5.49	2.50
Jig	423	391	0.0812	4.81	2.25

Table 2: Statistics on tune-level note networks, averaged by idiom.

4 Results

4.1 Tune Level

Figure 1 shows the sheet music and corresponding note network for classic 4/4 march "Scotland the Brave." The most central note on the graph is a C eighth note, with both highest in-degree and highest betweeness centrality.[5] A quick scan of the sheet music confirms that this makes sense: C eighth notes appear twice (on beats 3 and 4) in the first and third measures of the first, second, and fourth lines, as well as once in all but three other measures of the tune.

The directed loop formed by nodes in the green modularity class correspond to the "dot-cut" run of 16th notes at the end of the first line, a gesture that appears only once in the tune. The light blue modularity class encompasses notes that start the second phrase of lines one, two, and four (measure three of those lines), and the orange modularity class holds notes that start the first phrase of those same lines. In this way, we observe that the network, and network statistics, to appear to capture many features of the tune.

We generated tune-level note networks for each 4/4 March, Reel, and Jig in the dataset, and computed statistics on each graph. Individual tune statistic were then averaged within each idiom. Diameter and average path length data was computed/included only for strongly connected tunes. Results are presented in table 2.

Interestingly, the proportion of tunes that are strongly connected, 88.5%, is significantly higher than what we would expect to find on arbitrary networks of the same size and order. To determine this expected number of strongly connected graphs, we selected a tune at random among the 4/4 marches, jigs, and reels in our dataset, and created an Erdős–Rényi random graph with the same number of nodes and edges as that tune. Among 100,000 such

[5] We use betweeness centrality as a core measure of node importance throughout, as a high betweeness centrality implies that a node is key to linking various pieces of the melody/tune. In contrast, in-degree doesn't convey information beyond the immediate neighbors of a node, and eigenvector or Page Rank centrality considers the importance of adjacent nodes, with which we're not particularly concerned.

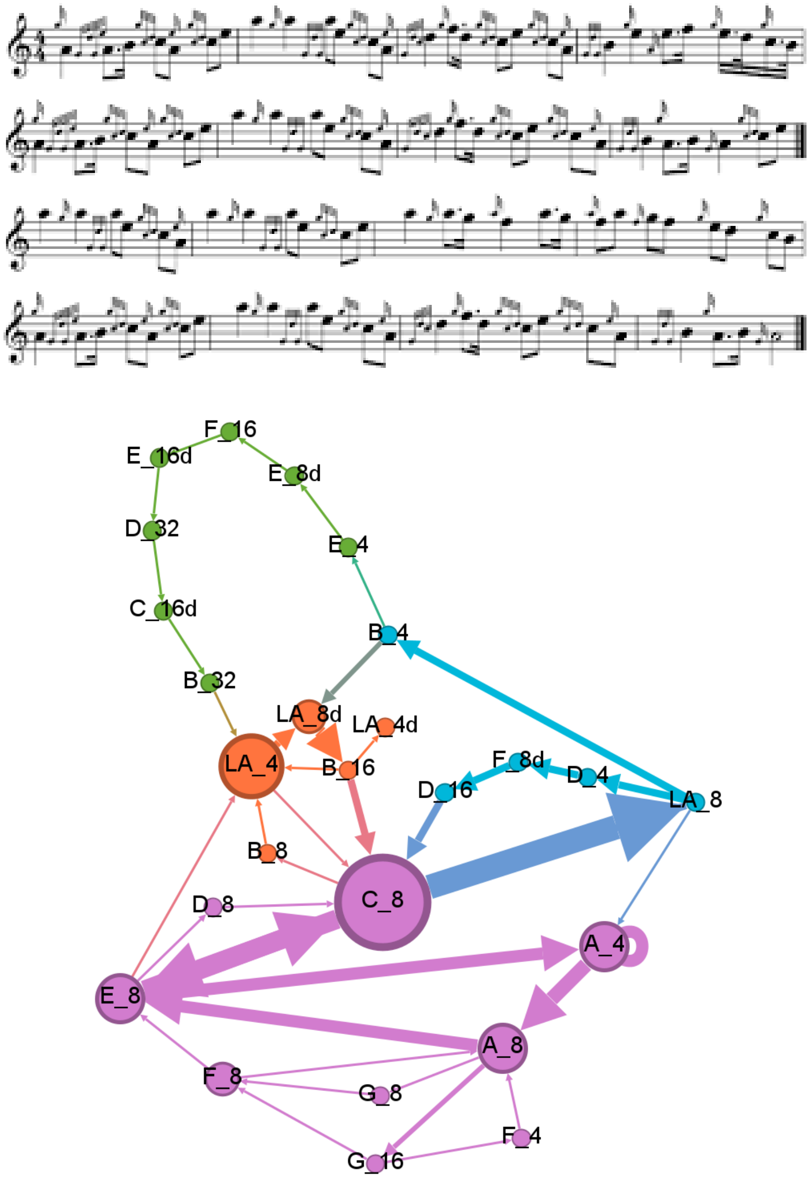

Figure 1: The GHB sheet music for "Scotland the Brave," and the corresponding note network. Nodes are sized based on betweeness centrality, and colored by modularity class.

graphs, 29.7% were strongly connected. This suggests a high level of repetition in ceòl beag tunes, as a disconnected note network necessarily implies the exitance of non-repeated notes.

Notably 86.9% of 4/4 marches, 81.9% of reels, and 92.4% of jigs are strongly connected. This also aligns with knowledge of these idioms: jigs almost always repeat their parts (every two lines of music is played twice), whereas reels generally don't have part repeats (though will still usually repeat particular phrases), and 4/4 marches fall somewhere in between the two.

We next observe that the mean average clustering coefficient across tune-level note networks is highest for reels and jigs and lowest for 4/4 marches. This seems to suggest that marches are more varied in the nodes (and thus metric denominations) that appear consecutively than the other two idioms. This is supported by the observation that while there are equivalent numbers of reels and 4/4 marches - and nearly twice as many jigs as either - the idiom-level note network for 4/4 marches has size and order nearly twice that of the other two idiom-level networks (table 1). This tells us that 4/4 marches use a broader spectrum of metric denominations than do reels or jigs, so it stands to reason that their tune-level note networks would be less clustered around particular notes and metric denominations.

The generalization above is further validated by the split in mean average path length and mean diameter values for 4/4 march networks, versus for jigs and reels. While jigs and reels have near equivalent mean diameter and mean average path length across tunes, those measures are each higher for 4/4 marches. This again suggests that the variety of metric denominations used in 4/4 marches is greater than that for either jigs or reels, as any two notes of particular pitch and duration are likely to appear further apart in a 4/4 march than a jig or reel.

4.2 Idiom Level

4.2.1 4/4 Marches

Figure 2 shows the aggregated idiom-level note network for 4/4 marches; notes are sized by betweeness centrality, and colored by modularity class. While nodes of all common metric denominations[6] are present, eighth notes, along with quarter notes, appear most central to the network. This aligns with our expectations for 4/4 marches, which anecdotally primarily use eighth and quarter note level divisions. Similarly, whole and half notes which are rarely seen in common 4/4 marches, appear on the fringes of the network. Interestingly, dotted

[6] Full, half, quarter, eighth, sixteenth and thirty-second notes, as well as their dotted versions

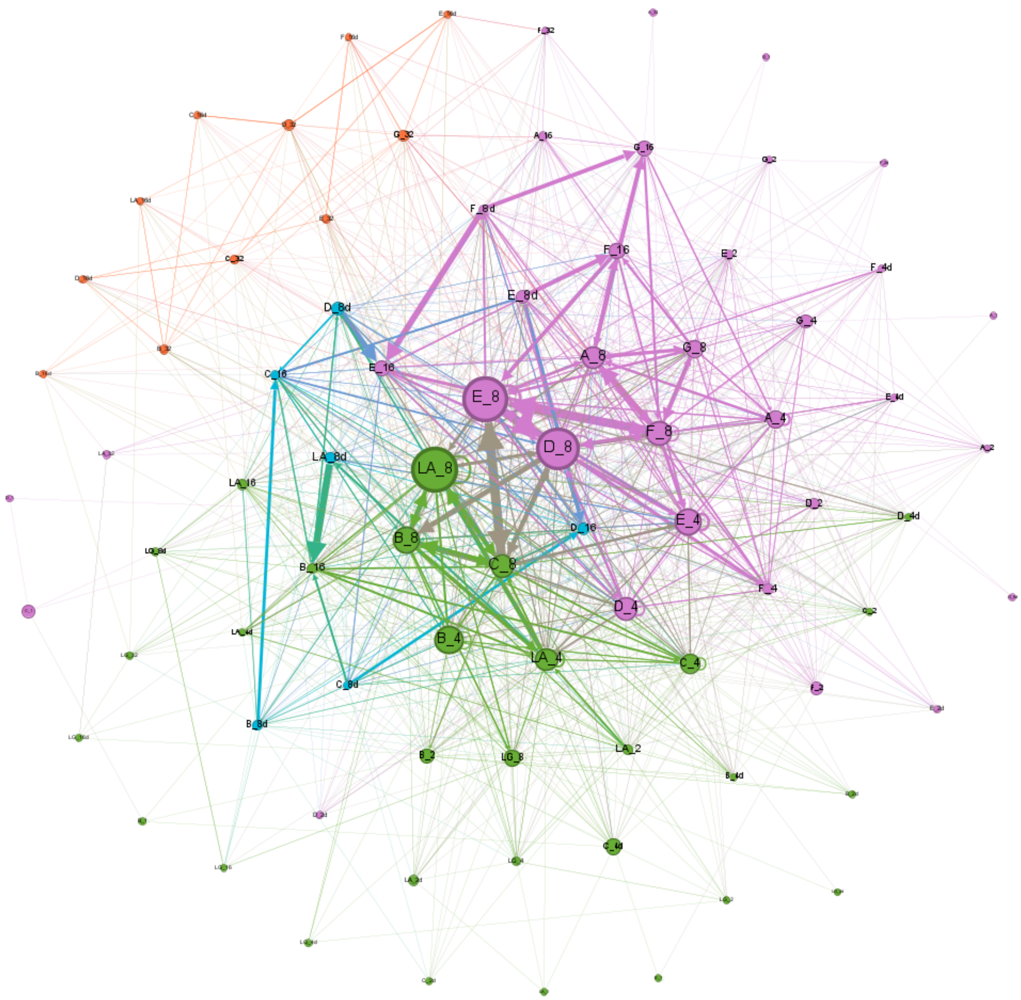

Figure 2: Idiom-level note network for 4/4 marches

quarter notes appear less centrally than we might expect, suggesting that the majority of 4/4 march couplets are played with a “round,” rather than “pointed” feel.

The two main modularity classes on the graph - green and purple - appear to capture an imperfect split between high-hand notes (D, E, F, high G and high A), and low-hand notes (low A, low G, B, C, D).[7] This agrees with accepted intuition around melodies - namely that melodies with adjacent notes that are closer in pitch are more pleasing to the ear/feel more natural. It therefore makes sense that a low-hand note is more likely to precede another low-hand note than a high-hand note, and vice versa.

The diameter of the 4/4 march idiom-level note network is 4, and the average path length is 1.94, both of which are well below the mean across individual tune networks as expected.

4.2.2 Jigs

Figure 3 shows the aggregated idiom-level note network for jigs; as above, nodes are sized by betweeness centrality and colored by modularity class. Here eighth notes dominate the most central positions in the network. This makes sense, as the feel of jigs is often characterized by a consistent flow of eighth note triplets. We observe a much higher prevalence of self-loops in the jig network versus that of the 4/4 march or reel networks. This is due in part to the consistency in the use of eighth notes in jigs, meaning that a repeated pitch is more likely to coincide with a repeated duration than in either of the other idioms, as well as to the prevalenve of “GDE”s in jigs. “GDE”s are a common gesture on the GHB and in jig specifically that consists of three notes (usually the same pitch) ornamented by a high G, E, then D gracenote (see figure 4).

Similar to the 4/4 march network, the two main modularity classes appear to split the network along the high-hand/low-hand line (in this case, D being counted as a high-hand note).

Jigs are the only idiom network that is not strongly connected, meaning diameter and average path length data is not available. We don’t find this distinction otherwise particularly informative, as it simply implies there is one tune that uses a note one time that no other tune uses (for example, could be something uncommon like a particular tune ending on a B whole note).

[7] D can be considered either a low-hand or high-hand note

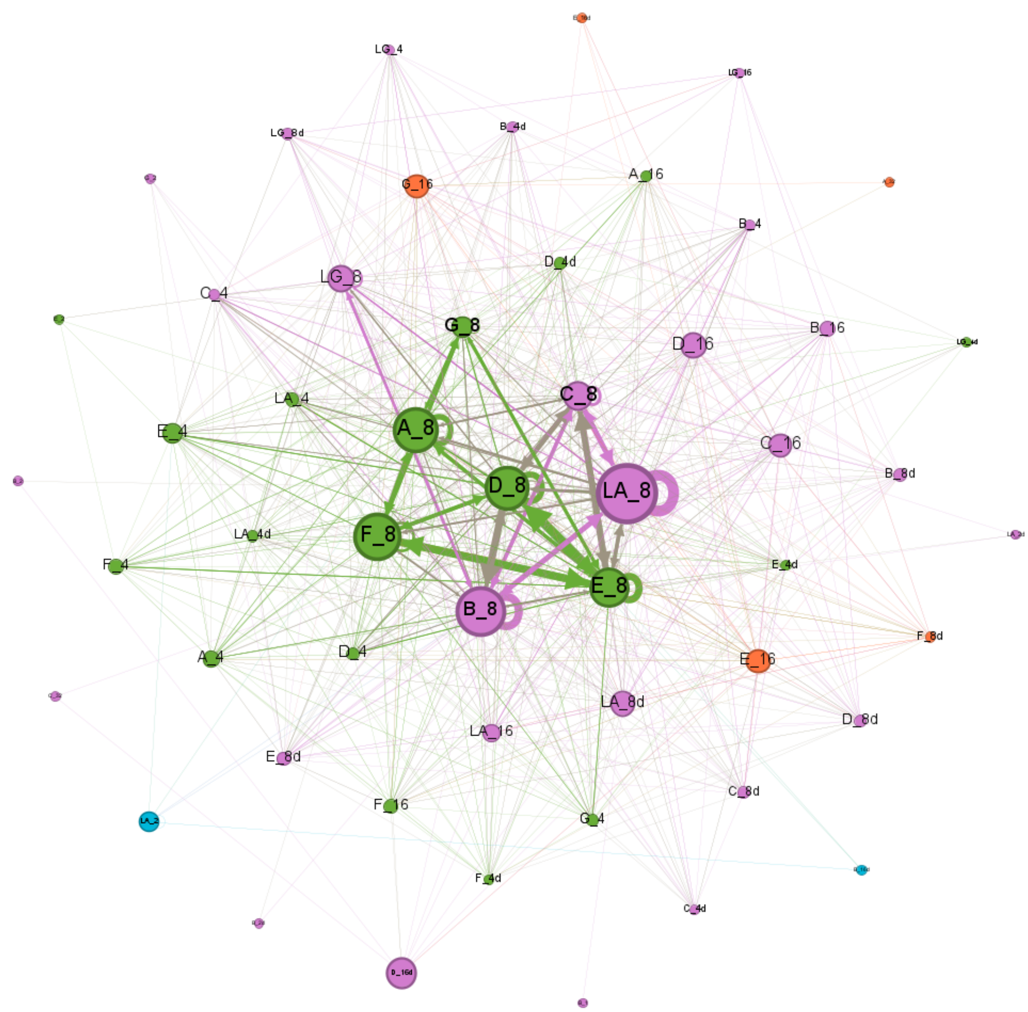

Figure 3: Idiom-level note network for jigs

Figure 4: Traditional jig "The Kesh Jig" arrranged for GHB; an excellent example of the prevalence of "GDE"s in bagpipe jigs. The first beat of measures 1,2,5,6,8,9,11,12,13, and 16 are all "GDE"s

4.2.3 Reels

Figure 5 shows the aggregated idiom-level note network for reels. Here again eighth notes are most central, followed by dotted eighth notes and sixteenth notes. This reflects a core division in the way reels are played, either with a "round" feel (primarily consisting of eighth notes) or with a "pointed" feel, consisting of alternating dotted eighths and sixteenths (figure 6).

This division between "round" and "pointed" reels is also evident in the division between the orange and purple modularity classes. Interestingly, this division is picked up instead of the high-hand/low-hand division evident in the modularity classes of 4/4 marches and jigs.

The diameter of the reel idiom-level tune network is 4, and the average path length is 1.90. Again these are lower than the mean across tune-level networks as expected.

4.3 Random Walks

Note networks, and especially idiom-level note networks, also have potential as generative tools. Any tune can be conceptualized as a walk along its corresponding note network (either tune or idiom level). Likewise, an arbitrary walk on an idiom-level note network could be interpreted as a tune. Therefore we can use our note networks as Markov Chain tune generators. We allow the user to pick the starting note s, and then randomly select

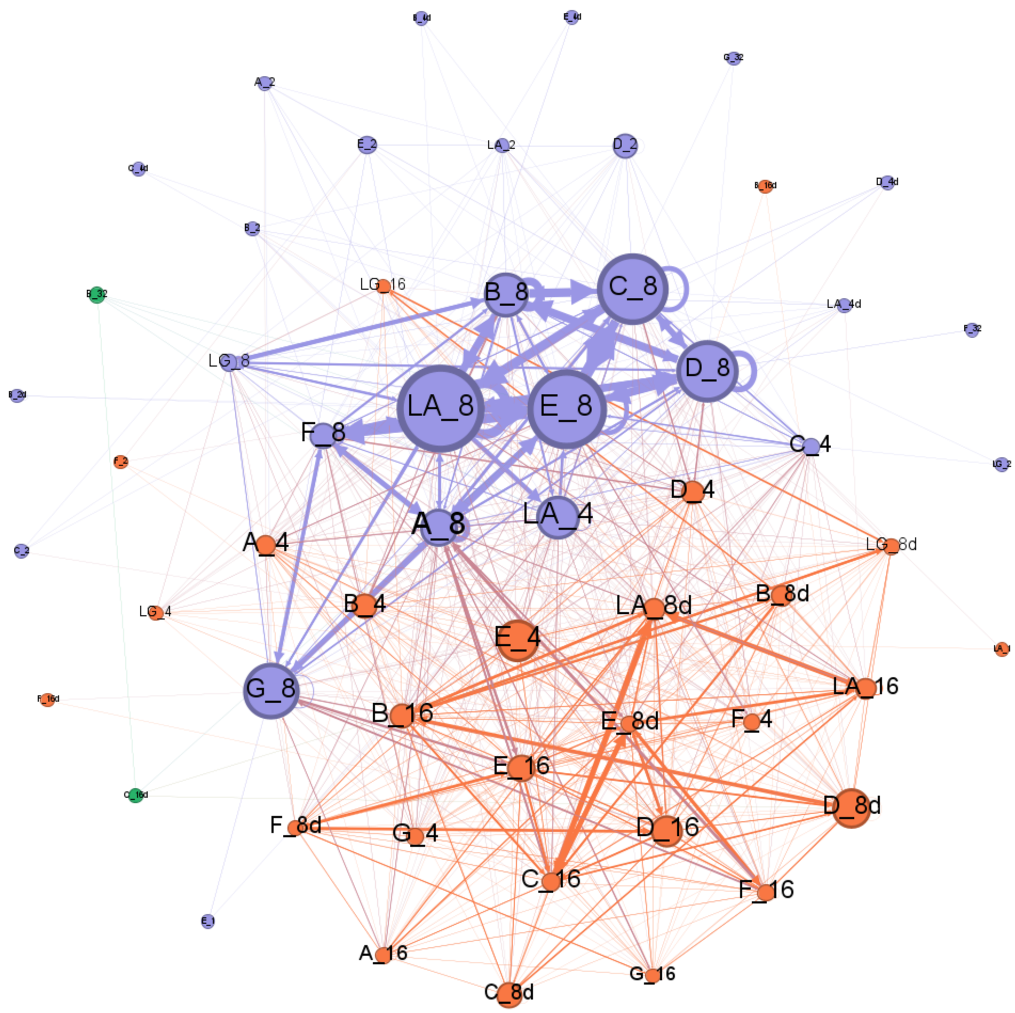

Figure 5: Idiom-level note network for reels

Figure 6: Example of a “pointed” reel (top) versus a “round” reel (bottom).

the next note from among the neighbors of s with probability based on the edge weights between s and each neighbor. We continue this process for some set total duration of notes, and return the results as a tune.

Unfortunately, tunes generated this way make little sense rhythmically. Ceòl beag is, like most western music, organized into measures of fixed length (determined by the time signature), but this structure is not directly encoded in the note network itself. As a result, tunes generated via random walks on the network often use metric denominations in ways totally counter-intuitive to human musicians (e.g. consistently tying notes across bars and beats, or making the tune punishingly syncopated, etc.). At best this makes the tunes near impossible to read, and at worst downright confusing to the ear. To remedy this, we generate the tune one measure at a time, forcing the random walk to adhere to the total duration of each measure, and thus eliminating ties across measures. This helped with tune readability, but did not fully fix the issue of unnatural syncopation within measures. The issue was worst in 4/4 marches and reels because of their relative wealth of possible metric values. On the other hand, because of their consistent eighth note rhythmic feel, we were able to generate jigs with a modicum of success. In practice we ended up generating many possible measures,

Figure 7: "The Beveridge Breakdown," a jig for GHB generated via Markov Chain on the jig note network.

and choosing the ones that made most sense/were most pleasant to the ear.

Figure 7 shows an example of a tune generated this way. The first line was generated entirely via random walk on the jig idiom-level note network, as was the third. The second and fourth lines were added in order fit the tune into common ceòl beag jig format, with a slight modification made to the last measure of lines 2 and 4 so that the tune would melodically resolve. All embellishments were added as deemed appropriate by the author. While somewhat unusual, the tune does function melodically, and may even be considered pleasant. This suggests that while perhaps not suitable for wholesale tune generation, random walks on note networks may be a useful idea generation tool for a composer of ceòl beag, especially when combined with prior knowledge of GHB embellishments and ceòl beag tune structure.

5 Conclusion

We have shown that networks built from note transitions in ceòl beag pieces convey large amounts of information about individual tunes and the idioms they comprise. 4/4 marches are found to have more rhythmic variation than jigs or reels, while all show significant levels of repetition. The idiom-level networks for 4/4 marches and jigs exhibit modularity classes that capture the distinction between high-hand and low-hand notes, while the modularity classes of the reel idiom-level network instead capture the distinction between "round" and "pointed" reels. We have also shown that note networks have potential as generative tools, with Markov Chains able to create unique and often plausible melodies from the idiom-level networks. Directions for future work include:

- Analysis of more idioms. Investigating the difference between reels and hornpipes (a famously murky distinction) via networks would be particularly interesting.
- Implementation of more holistic network comparison methods. While network statistics do reveal interesting comparisons between tunes and idioms, an approach more grounded in network structure would likely provide more comprehensive results.
- Analysis of a broader selection of tunes. A larger corpus would lead to more reliable results.

References

[1] *Bagpipe Tunes*. https://bagpipetunes.intertechnics.com/. Accessed: 2024-05-03.

[2] Suman Kulkarni et al. "Information content of note transitions in the music of J. S. Bach". In: *Phys. Rev. Res.* 6 (1 Feb. 2024), p. 013136. DOI: 10.1103/PhysRevResearch.6.013136. URL: https://link.aps.org/doi/10.1103/PhysRevResearch.6.013136.

[3] *What is Piobaireachd?* https://www.piobaireachd.co.uk/what-is-piobaireachd. Accessed: 2024-05-03.