



The Pendular Graph: Visualising Hierarchical Repetitive Structure in Point-set Representations of the POP909 Music Dataset

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Contents

- Introduction & motivation
- Contributions of this paper
- The pendular graph
- Hierarchicalisation of the POP909 annotations
- Limitations and future work



Repetition in music

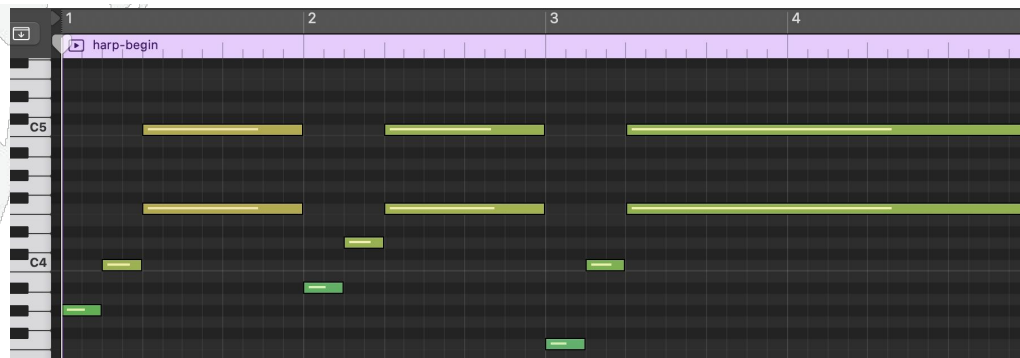
- It has long been suggested that composers introduce repetitions carefully to emphasise music ideas (Schoenberg, 2010).
- Recognising repetitive patterns is also an important step for understanding music (Meyer, 2008; Lerdahl and Jackendoff, 1996).

- ❑ Schoenberg, A. (2010). *Style and idea: Selected writings*. Univ of California Press.
- ❑ Meyer, L. B. (2008). *Emotion and meaning in music*. University of Chicago Press.
- ❑ Lerdahl, F., & Jackendoff, R. S. (1996). *A Generative Theory of Tonal Music, reissue, with a new preface*. MIT press.



Repetition in music

- Music tends to be full of hierarchical repetitions.

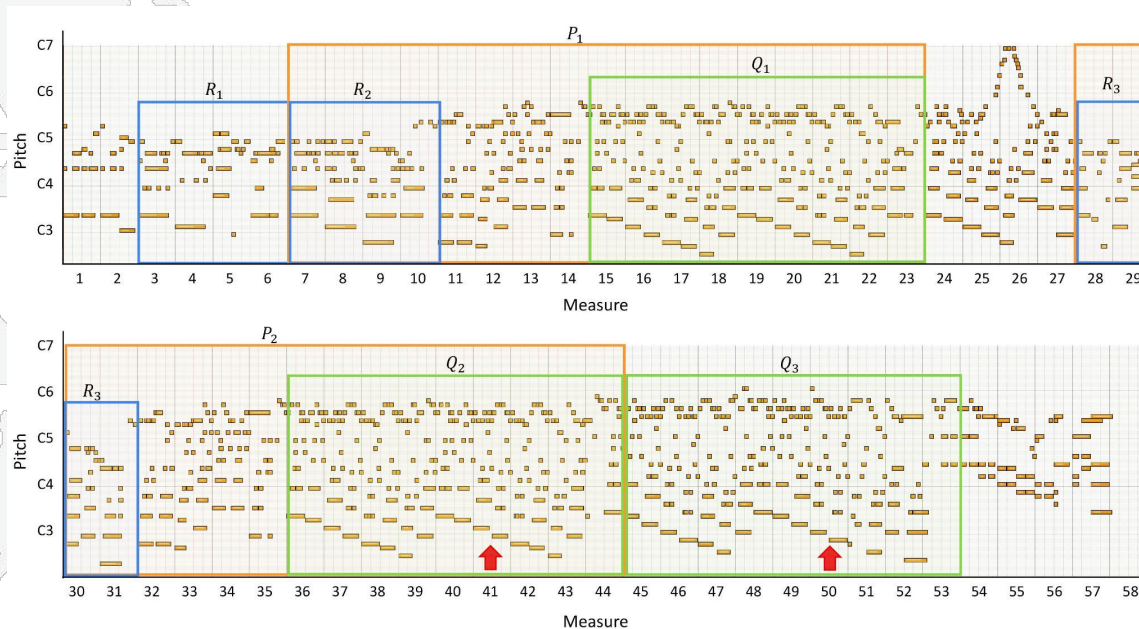


Four bars piano reduction of "Waltzing in the Rain" from *Sky*, composed by Vincent Diamante, and an example of piano-roll format.



Repetition in music

- Music tends to be full of hierarchical repetitions.



"Passerby", A-Han in piano roll format, in which repetitive patterns are highlighted in bounding boxes with the same colour.



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Limitations of existing music structure visualisation tools

- Comprehending musical structure has been shown to help people remember or understand music better (Deutsch, 1980).
- A lot of music structure visualisation tools have been developed but many of these tools suffer either from a lack of interactivity (Wattenberg, 2002), or are now unusable due to software dependency or maintenance issues (Nikrang et al., 2014).

- ❑ Deutsch, D. (1980). The processing of structured and unstructured tonal sequences. *Perception & psychophysics*, 28(5), 381-389.
- ❑ Wattenberg, M. (2002). Shape of song. <http://www.turbulence.org/Works/song/>
- ❑ Nikrang, A., Collins, T., & Widmer, G. (2014). PatternViewer: An application for exploring repetitive and tonal structure. *J.-SR Jang, M. Goto, & JH Lee (Chairs.), Late-Breaking demo. ISMIR.*



Contributions

- Introduce a web-based interface where hierarchical annotations of 909 songs can be explored and played back.

- Gao, C., & Collins, T. (2023). The Pendular Graph: Visualising Hierarchical Repetitive Structure in Point-set Representations of the POP909 Music Dataset. Accepted by *25th International Conference in Human-Computer Interaction (HCI 2023 Conference) - Late Breaking Work*.



Limitations of existing datasets with structure annotations

- Existing music structure visualisation tools are highly relied on annotated data, while existing music datasets with structural annotations tend to be either
 - a) small in terms of items in the corpus, but with detailed annotations (Collins, 2013, Tomašević et al, 2021) or
 - b) larger as a corpus, but with **linear annotations** only (Dai et al., 2020)
 - E.g., "intro, verse 1, verse 2, chorus,..." or "iAAB..." for short

- Collins, T. (2013). Discovery of repeated themes and sections. Retrieved 4th May, http://www.musicir.org/mirex/wiki/2013:Discovery_of_Repeated_Themes_&_Sections.
- Tomašević, D., Wells, S., Ren, I. Y., Volk, A., & Pesek, M. (2021). Exploring annotations for musical pattern discovery gathered with digital annotation tools. *Journal of Mathematics and Music*, 15(2), 194-207.
- Dai, S., Zhang, H., & Dannenberg, R. B. (2020). Automatic analysis and influence of hierarchical structure on melody, rhythm and harmony in popular music. In *Proceedings of the Joint Conference on AI Music Creativity*.



Contributions

- Introduce a web-based interface where hierarchical annotations of 909 songs can be explored and played back.
- Develop a method for taking a linear annotation as input, and converting it to a hierarchical annotation as output

- Gao, C., & Collins, T. (2023). The Pendular Graph: Visualising Hierarchical Repetitive Structure in Point-set Representations of the POP909 Music Dataset. Accepted by *25th International Conference in Human-Computer Interaction (HCI 2023 Conference) - Late Breaking Work*.

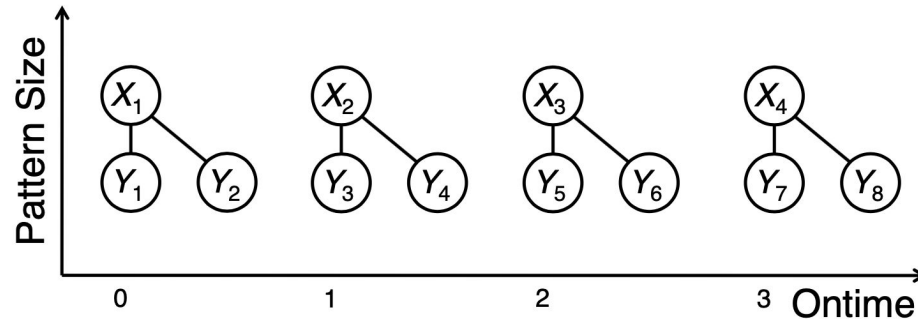
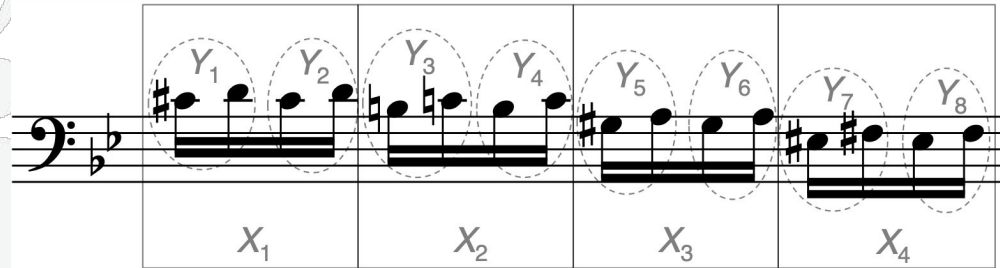


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POP909 Pendular Graphs



- Deutsch, D., & Feroe, J. (1981). The internal representation of pitch sequences in tonal music. *Psychological review*, 88(6), 503.
- Collins, T. E. (2011). *Improved methods for pattern discovery in music, with applications in automated stylistic composition*. Open University (United Kingdom).



POP909 Pendular Graphs

Input a number (0-909) to select a song: ← 1. Song Selection Panel

2. Selected Song Name
The structure of song "002" is visualised.

3. Playback Controls

4. Pendular Diagram Visualisation

5. Piano-Roll Visualisation

- ❑ <https://pendular-graph.glitch.me/>
- ❑ Gao, C., & Collins, T. (2023). The Pendular Graph: Visualising Hierarchical Repetitive Structure in Point-set Representations of the POP909 Music Dataset. Accepted by *25th International Conference in Human-Computer Interaction (HCI 2023 Conference) - Late Breaking Work*.



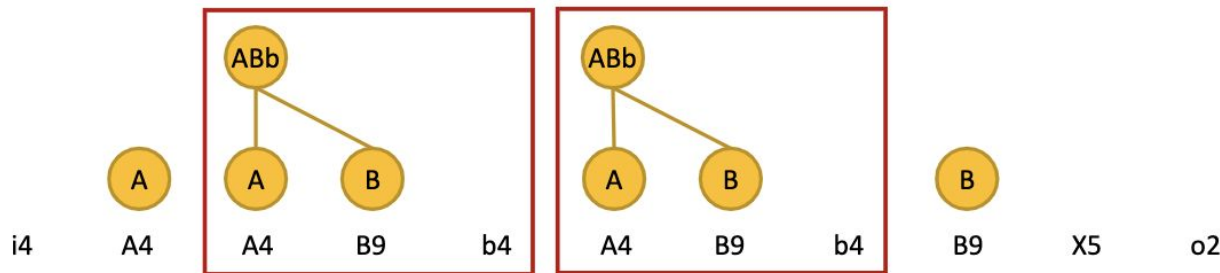
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The POP909 dataset

- Piano arrangements of 909 popular Chinese songs in MIDI format.
- Phrase-level repetitive structure labels are provided (Dai et al., 2020).



Hierarchical structure analysis of “123 Pinocchio”, Hey Girl. The smallest repetitive phrase is labelled by a letter followed by the number of bars. Phrases labelled with the same letter are repetitive, and larger repetitive patterns are highlighted by bounding boxes

- Dai, S., Zhang, H., & Dannenberg, R. B. (2020). Automatic analysis and influence of hierarchical structure on melody, rhythm and harmony in popular music. In *Proceedings of the Joint Conference on AI Music Creativity*.



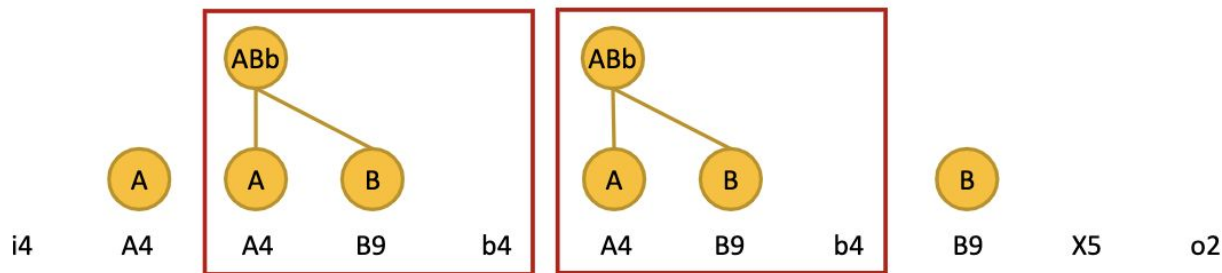
Linear vs Hierarchical

- A linear annotation (not hierarchical) :

- If a piece of music is annotated as “intro, verse, verse, chorus, verse, chorus, chorus” (or, more succinctly, “ABBCBCC”), this is a linear annotation.

- Hierarchical annotation:

- Phrases that appear together will be grouped.



Hierarchical structure analysis of “123 Pinocchio”, Hey Girl. The smallest repetitive phrase is labelled by a letter followed by the number of bars. Phrases labelled with the same letter are repetitive, and larger repetitive patterns are highlighted by bounding boxes



Hierarchicalisation of the POP909 Annotations

- An algorithm to convert phrase-level repetitive pattern labels into a hierarchical labelling:
 - The function `get_repeat_subsequences()` will return repetitive substrings.
 - The following steps filter out repetitive patterns that involve non-repetitive phrases or appear only in larger patterns.

Algorithm 1 Hierarchicalises linear repetitive pattern labels.

Input: Linear, phrase-level repetitive pattern labels (\mathbf{P}) of the POP909 dataset

Output: Hierarchical repetitive pattern labels

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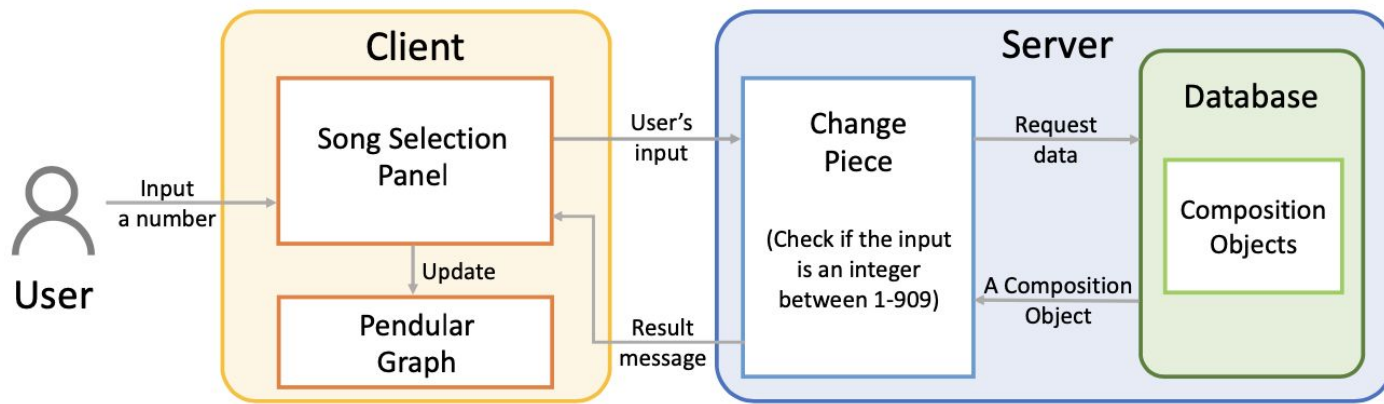
1: for  $p \in \mathbf{P}$  do
2:   Separate phrase labels and bar counts into two arrays as  $\mathbf{V}_{\text{Phr}}$  and  $\mathbf{V}_{\text{Bar}}$ .
3:    $\mathbf{V}_{\text{Rep}} \leftarrow \text{get\_repeat\_subsequences}(p)$ 
4:   for  $v \in \mathbf{V}_{\text{Rep}}$  do
5:     if Non-repetitive patterns (e.g., “X”, “x”, “i”, and “o”) involved in  $v$  then
6:       Filter out  $v$ 
7:     else if  $v$  only appears in larger patterns then
8:       Filter out  $v$ 
9:     else
10:      if An occurrence of  $v$  overlaps the previous occurrence then
11:        Filter out the current occurrence of  $v$ 
12:      end if
13:      if The occurrence count of  $v > 1$  then
14:        Push  $v$  into  $\mathbf{V}_{\text{Out}}$ 
15:      end if
16:    end if
17:  end for
18:  return  $\mathbf{V}_{\text{Out}}$ 
19: end for

```



Interface

- The web interface is developed by using JavaScript packages, e.g., p5.js.
- The server side is developed with Fastify and the Node Fetch APIs.
- The MAIA Util package (Collins and Coulon, 2019) is used when processing music data, and Tone.js (Mann, 2015) enables the songs to be played back dynamically in the browser.



□ Collins, T., & Coulon, C. (2019, December). MAIA Util: an NPM package for bridging web audio with music-theoretic concepts. In *Proceedings of the web audio conference* (pp. 47-52).

□ Mann, Y. (2015, January). Interactive music with tone.js. In *Proceedings of the 1st annual Web Audio Conference*. Citeseer.



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Why do we need pattern discovery algorithms¹?

- Pattern occurrences begin/end at bar beginnings/endings in hierarchical annotations for 909 songs.

- Visualisation is restricted to the labelled POP909 dataset

1. Given a point set D , return subsets $p_{1,1}, p_{2,1}, \dots, p_{m,1}$ of D such that each $p_{i,1}$ is *musically noticeable or important* due partly or wholly to its recurrence in more or less exact form elsewhere in D .
For each $p_{i,1}$, these more or less exact occurrences $p_{i,2}, p_{i,3}, \dots, p_{i,n_i}$ should also be returned.



The potential usage of the pendular graph

- As useful software tools for music analysts and composers.
- Music without well-organised hierarchical structure sounds incoherent and aimless, which is quite a common problem that exists in AI music generation. (Dai et al., 2022)
 - Visualise if music generated by AI has hierarchical repetitive structure.

□ Dai, S., Zhang, H., Dannenberg, R.B. (2020). Automatic analysis and influence of hierarchical structure on melody, rhythm and harmony in popular music. In *Proceedings of the 2020 Joint Conference on AI Music Creativity*, 2020.



Thanks!

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