

Quantum Annealing for Music Arrangement

Lucas Kirby

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Department of Physics, Durham University

Overview

Motivations

Theory

Music arrangement

Quantum annealing

Methods

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Conclusions

Motivations

Motivations

- Small lit review¹
- Quantum computer music
- My own novel adaption of the method
- THIS IS MY OWN IDEA

¹Emilios Cambouropoulos. **'The Local Boundary Detection Model (LBDM) and its Application in the Study of Expressive Timing'**. In: *International Computer Music Association* (2011). ISSN: 2223-3881

Theory

Music arrangement

- Adaptation of previously composed pieces for practical or artistic reasons
- Traditionally complex and time-consuming
- This study focuses on **reduction**

The image displays a musical score for Beethoven's String Quartet No. 10, Op. 10, No. 3. The score is written for four instruments: Violin I, Violin II, Viola, and Violoncello. The key signature is three flats (B-flat, E-flat, A-flat), and the time signature is 4/4. The tempo/mood is marked 'Poco Adagio'. The score is divided into three systems. The first system shows the initial measures for each instrument. The second system, starting at measure 6, includes dynamic markings such as 'cresc.' (crescendo) and 'f' (forte). The third system, starting at measure 10, includes markings for 'espress.' (espressivo), 'p' (piano), and 'f' (forte). The notation includes various musical symbols such as notes, rests, and slurs.

Beethoven's String Quartet No. 10

Adiabatic quantum computing (AQC)

- *Materials* | heating and cooling a material to alter its physical properties
- *Quantum* | changing a quantum system from one Hamiltonian to another
- Done slowly and adiabatically to remain in the ground state

$$H(t) = \left(1 - \frac{t}{T}\right) H_0 + \frac{t}{T} H_p$$

Andrew Lucas. **'Ising formulations of many NP problems'**.

English. In: *Frontiers in Physics* 2 (Feb. 2014). Publisher: Frontiers.

ISSN: 2296-424X. DOI: [10.3389/fphy.2014.00005](https://doi.org/10.3389/fphy.2014.00005). (Visited on 14/10/2024)

Ising model

$$H_p(\sigma^z) = \sum_{i < j}^N J_{ij} \sigma_i^z \sigma_j^z + \sum_{i=1}^N h_i \sigma_i^z$$

Initial state

$$H_0 = h_0 \sum_{i=1}^N \sigma_i^x$$

Lucas, 'Ising formulations of many NP problems'

Quadratic Unconstrained Binary Optimisation

$$f(x) = \sum_{i < j}^N Q_{i,j} x_i x_j + \sum_i^N Q_{i,i} x_i$$

- Encodes problem solution into Hamiltonian's ground state
- Sent to the QPU for optimisation

How to combine them?

Methods

Problem formulation

1. Split score into musical phrases
2. Arrange phrases into a graph
3. Solve graph problem using QPU
4. Construct arrangement from solution

1. Split score

Local boundary detection model (LBDM)

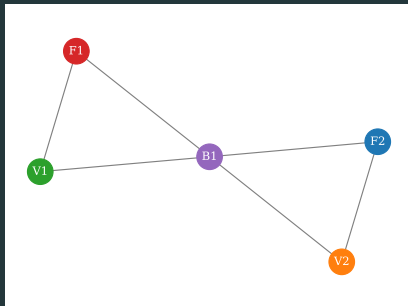
$$S_i = x_i \times (r_{i-1,i} + r_{i,i+1})$$

Emilios Cambouropoulos. 'The Local Boundary Detection Model (LBDM) and its Application in the Study of Expressive Timing'. In: *International Computer Music Association* (2011). ISSN: 2223-3881

The image displays a musical score for three instruments: Flute, Violin, and Bassoon, in 4/4 time. The Flute part features a series of eighth notes with red stems and flags, indicating a specific timing or expression. The Violin part has a few notes with green stems and flags. The Bassoon part has a single note with a purple stem and flag. A purple line connects the Bassoon note to the Violin note, suggesting a relationship or boundary. The score is presented in a split format, with each instrument on its own staff.

2. Create graph

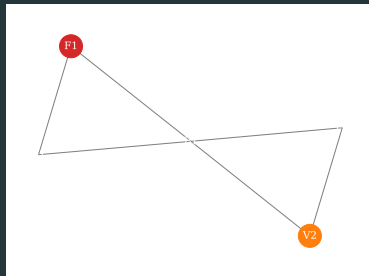
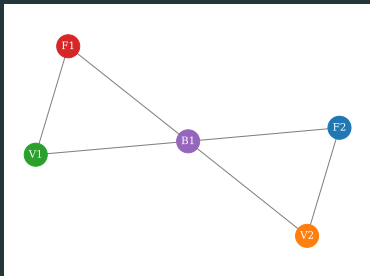
A musical score for three instruments: Flute, Violin, and Bassoon, in 4/4 time. The Flute part (top staff) begins with a quarter rest, followed by a sequence of eighth notes: G4, A4, B4, C5, D5, E5, and F5. The Violin part (middle staff) has a whole rest for the first two measures, then plays a half note G4 in the third measure and a half note A4 in the fourth measure. The Bassoon part (bottom staff) plays a whole note G2 in the first measure and a whole note A2 in the second measure, with a slur connecting the two notes. The score ends with a double bar line.



3. Solve graph

Maximal independent set (MIS)

Largest subset of nodes such that no nodes within the subset are connected by an edge

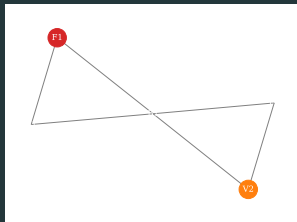


4. Construct arrangement

Flute

Violin

Bassoon



Results

Excerpt

Poco Adagio

Violin I
sotto voce
Poco Adagio

Violin II
sotto voce
Poco Adagio

Viola
sotto voce
Poco Adagio

Violoncello
sotto voce
Poco Adagio

6

cresc.

cresc.

cresc.

10

espress.

p

f

espress.

p

f

cresc.

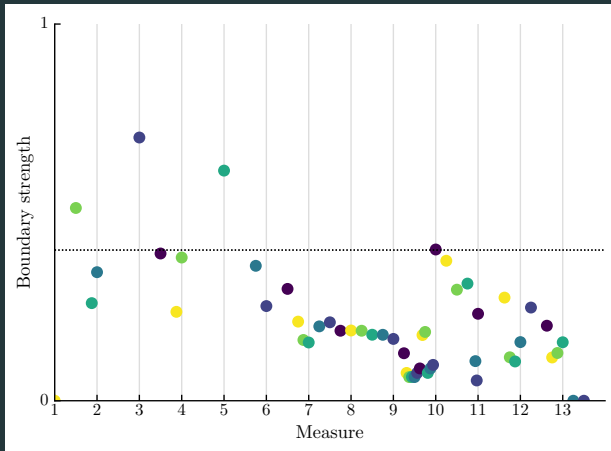
p

f

p

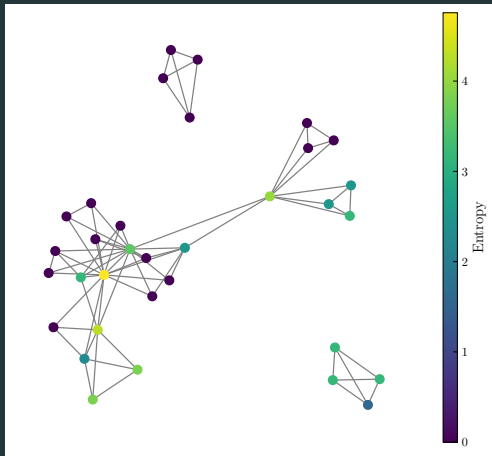
String Quartet No. 10 by Ludwig van Beethoven

Phrase detection



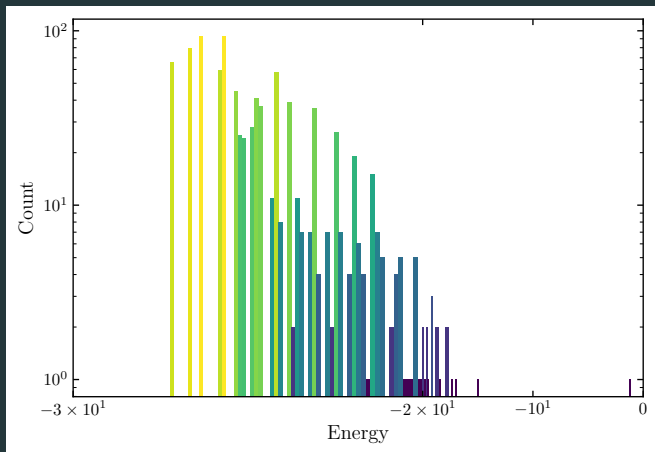
Boundary strengths for the Violin I part

Problem graph



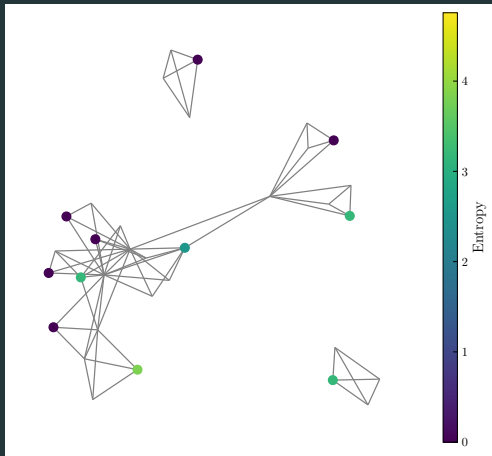
Problem graph with 33 nodes and 70 edges

Solutions



Returned solutions for 1000 reads

Example solution



Solution graph returning a subset of 11 nodes

Final arrangement

Poco Adagio

Violin I
sotto voce
Poco Adagio

Violin II
sotto voce
Poco Adagio

Viola
sotto voce
Poco Adagio

Violoncello
sotto voce

6

cresc.

cresc.

cresc.

10

espress.

p

f

espress.

p

f

cresc.

p

f

p

f

Selected phrases

Poco Adagio

sotto voce

7

espress.

cresc.

p

11

f

Final arrangement

Conclusions

Conclusions

- Successful in creating a valid single-part reduction
- Advantage over classical algorithms Jiun-Long Huang, Shih-Chuan Chiu and Man-Kwan Shan. **‘Towards an automatic music arrangement framework using score reduction’**. In: *ACM Trans. Multimedia Comput. Commun. Appl.* 8.1 (Feb. 2012), 8:1–8:23. ISSN: 1551-6857. DOI: 10.1145/2071396.2071404. (Visited on 05/12/2024)
- Removes skill barrier for music arrangement



Future work

- Increased problem size
- Parametric variation of LBDM
- Physical limitations of instruments
- Reduction to more than one part
- Quality comparison of computer arrangements M. Pearce and Geraint A. Wiggins. **‘Towards A Framework for the Evaluation of Machine Compositions’**. In: *Proceedings of the AISB’01 Symposium on Artificial Intelligence and Creativity in the Arts and Sciences*. 2001

Thank you!

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Boundary strength

$$S_i = x_i \times (r_{i-1,i} + r_{i,i+1})$$

$$r_{i,i+1} = \frac{|x_i - x_{i+1}|}{x_i + x_{i+1}}$$

Normalisation

$$S'_i = \frac{S_i - \min(S_i)}{\max(S_i) - \min(S_i)}$$

Weighting

$$S = \frac{1}{3} (S'_{\text{pitch}} + 2S'_{\text{IOI}})$$

Cambouropoulos, 'The Local Boundary Detection Model (LBDM) and its Application in the Study of Expressive Timing'

$$f(x) = A \sum_{ij \in E} x_i x_j - B \sum_i W_i x_i$$

Lucas, 'Ising formulations of many NP problems'

$A/B \geq 2 \max(W)$ to weight the constraint term more heavily than any objective term

Phrase entropy

Shannon entropy

$$H(X) := - \sum_i P(x_i) \log_2 P(x_i)$$

Probability distribution

$$P(x_i) = \frac{n_i}{N}$$

You Li et al. **‘Automatic Piano Reduction of Orchestral Music Based on Musical Entropy’**. In: *2019 53rd Annual Conference on Information Sciences and Systems (CISS)*. Mar. 2019, pp. 1–5. DOI: 10.1109/CISS.2019.8693036. URL: <https://ieeexplore.ieee.org/document/8693036> (visited on 27/12/2024)