APPLYING BAYESIAN STRUCTURAL INFERENCE TO PITCH SEQUENCES IN MUSIC

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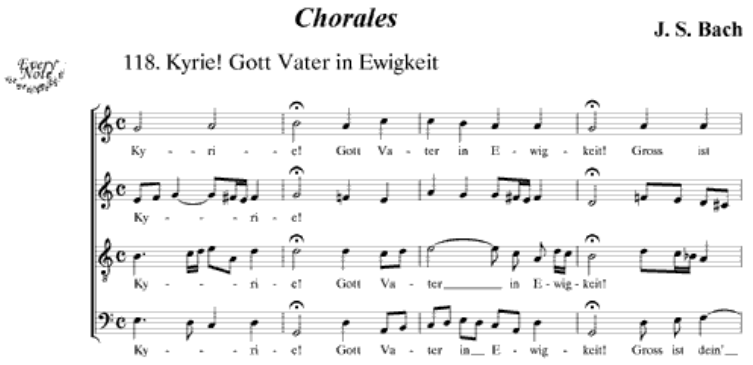


WHY MUSIC USING BSI?

A lot of similarity to languages. Has analogues to letters (notes, duration), words (measures or sequences), sentences (phrases), suggesting similar techniques can be used. Good candidate to apply BSI techniques to (don't have to assume a finite order Markov).

Information measures in music can be useful. E.g. genres can be discriminated using entropy measures (e.g. *Music viewed by its Entropy content: A novel window for comparative analysis*, G. Febres, K. Jaffé). Information measures can be obtained from BSI.

Can produce music samples from inferred machines as a "side effect". Another way to evaluate BSI performance.

PROJECT GOALS

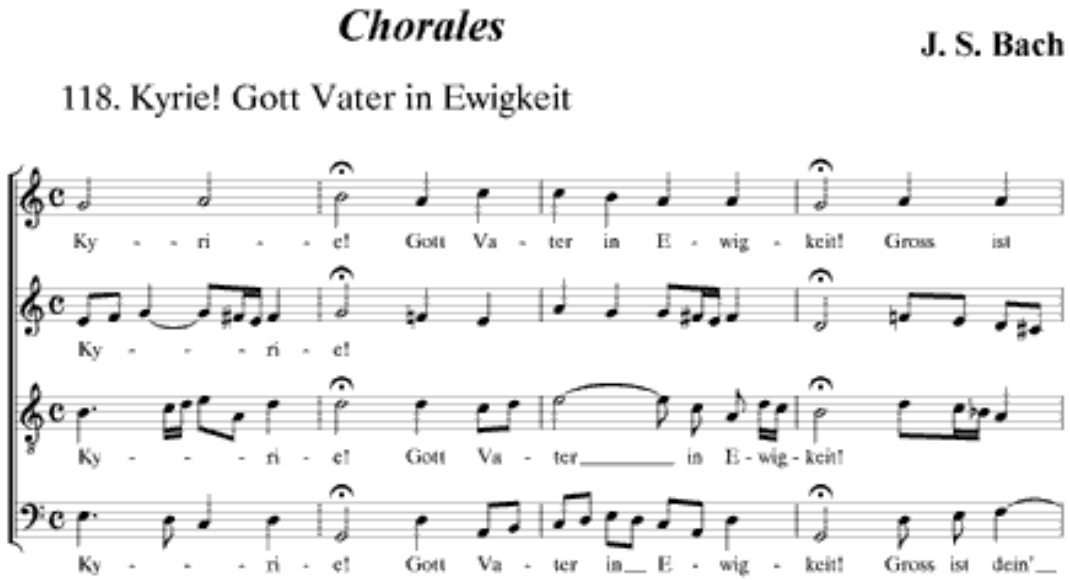
Apply Bayesian Structural Inference techniques to simplified music pieces. Using the posterior distribution, calculate various information quantities (excess entropy, crypticity, etc.)

Compare the information quantities for different composers and genres. Compare the entropy measures with those obtained using other methods.

See if one can find the correspondence between the inferred **ε** –machine topologies and music theory rules. E.g., is there a state corresponding to cadential sequences?

INPUT

Bach chorales available in music21 corpus.
Can extend to other composers.



Example: bwv371

Parameters (can be obtained using music21 toolkit) for each piece:

- Voices (Soprano, Alto, etc.)
- Pitches
- Duration
- Rests
- Chords
- Key signatures
- etc.

ISSUES WITH USING BSI

Assuming no prior knowledge about the structure of the machine, need to sample over all possible **ε** –machines of a given range of sizes.

- Potentially large alphabet size (7+), which leads to large number of **ε** –machines of a given size.

Dealing with that issue: get a sample of 1000-5000 randomly chosen **ε** –machines, find the most probable among those.

- Relatively short sequences (~100-200 symbols in my case)
- Several non-independent observables to chose from: pitch, duration, key, chord, etc.

Simple case: one part (Soprano), only considered pitch.

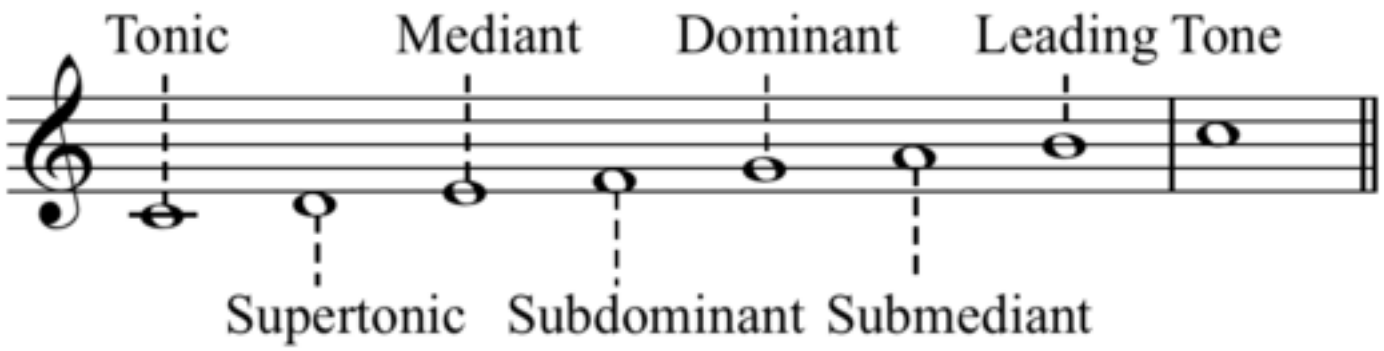
States	Machines
n	$F_{n;2}$
1	1
2	7
3	78
4	1,388
5	35,186

Number of **ε** –machines for 2 symbol alphabets. From Crutchfield, Ellison, Mahoney, 2009

USED DATA: EXAMPLE

bwv42.7

bwv42.7: soprano. Captures most of the melody



In scale degree representation: 7 symbols+1 for all the other pitches. Applicable to diatonic scale.

FROM PITCHES TO SCALE DEGREES EXAMPLE: BWV190.7-INST

2 sharps, mode major: D major key signature, ['D', 'E', 'F#', 'D', 'A', 'B', 'C#']

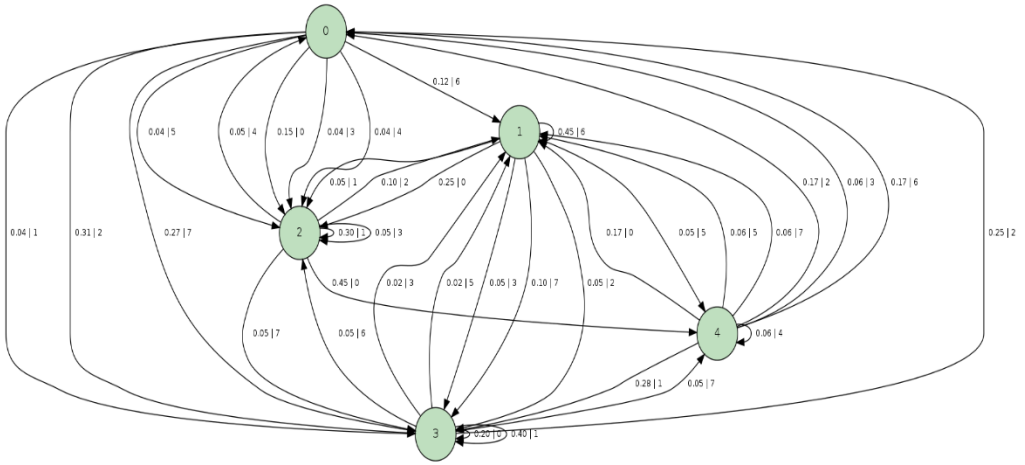
F#5 F#5 D5 E5 F#5 G5 E5 E5 E5 D5 D5 C#5 D5 E5 E5 E5 E5 F#5 D5 D5 D5 C#5 D5 E5 E5 D5 F#5 F#5 D5 E5 F#5 G5 E5 E5 E5 D5 D5 C#5 D5 E5 E5 E5 E5 F#5 D5 D5 D5 C#5 D5 E5 E5 D5 C#5 C#5 C#5 C#5 C#5 D5 D5 C#5 C#5 C#5 C#5 C#5 D5 D5 F#5 F#5 D5 E5 F#5 G5 F#5 F#5 E5 F#5 D#5 D#5 E5 F#5 F#5 D5 E5 F#5 G5 F#5 F#5 E5 F#5 D#5 D#5 E5 F#5 F#5 D5 E5 F#5 G5 E5 E5 E5 D5 D5 C#5

Scale degree representation (7 for notes not in key signature):

['2','2','0','1','2','7','1','1','1','0','0','6','0','1','1','1','1','2','0','0','0','6','0','1','1','0','2','2','0','1','2','7','1','1','1','0','0','6','0','1','1','1','1','2','0','0','0','6','0','1','1','0','6','6','6','6','6','0','0','6','6','6','6','6','0','0','2','2','0','1','2','7','2','2','1','2','7','7','1','2','2','0','1','2','7','2','2','1','2','7','7','1','2','2','0','1','2','7','1','1','1','0','0']

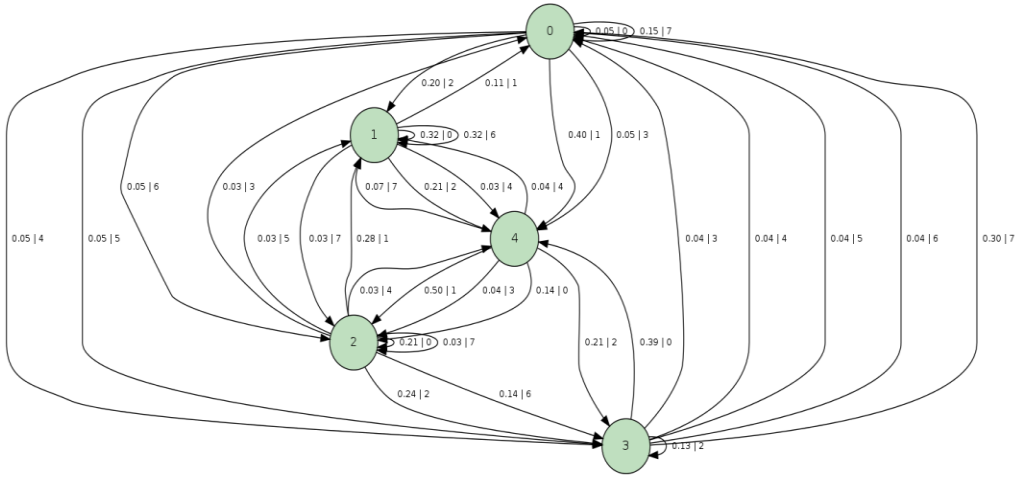
EXAMPLE: BWV190-INST INFERRED MACHINES

Highest probability machine, out of a random sample of 1000 machines with 5 states



bwv190.7-inst

Highest probability machine, out of a random sample of 5000 machines with 5 states



Random or inferred EM?

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EXAMPLE: BWV190.7-INST INFERRED MACHINE SAMPLE SEQUENCES

bwv190.7-inst

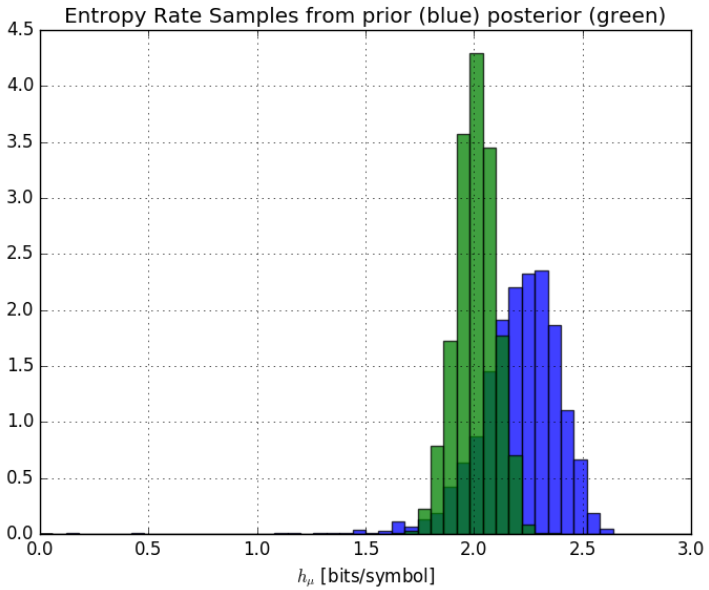
Random

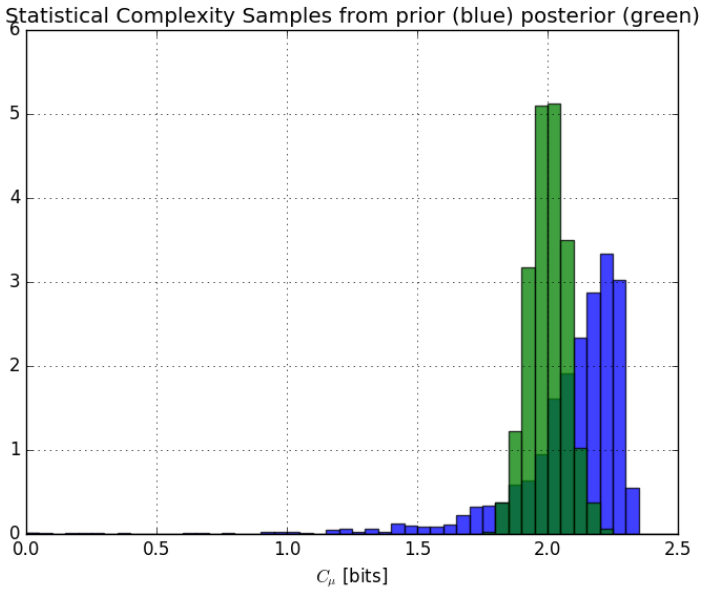
From inferred EM

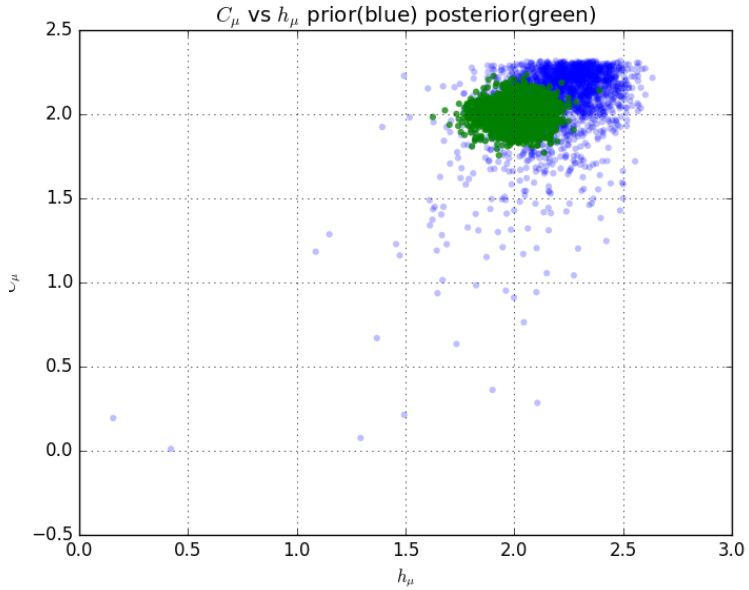
From inferred EM

Assuming the same rhythmic structure as the original piece: room for improvement. Can also add key progressions.

ENTROPY RATE AND STATISTICAL COMPLEXITY ESTIMATES FOR BWV190.7-INST







FUTURE WORK

Similarities in structure: could use BSI on several samples and infer the most probable model for all?

Exploring rhythmic entropy, chord progression entropy, etc.

Interpreting the obtained entropy measures, comparing them with those presented in literature.

REFERENCES

Time's Barbed Arrow: Irreversibility, Crypticity, and Stored Information. James P. Crutchfield, Christopher J. Ellison, John R. Mahoney, Phys. Rev. Lett. 103, 2009

Regularities unseen, randomness observed: Levels of entropy convergence. James P. Crutchfield, David P. Feldman, Chaos, 2003

Music Viewed by Its Entropy Content: A Novel Window for Comparative Analysis, Gerardo Febres, Klaus Jaffé, arxiv.org/abs/1510.01806