KY1701 Automatic Piano Reduction (Backend): Chord Identification

1155046896 JIN Xiamu
1155048011 Li Cheuk Yau

Focus in this semester

Rule-based V.S. Machine Learning

1. ASHES (rule-based algorithm)
2. Hidden Markov Model

ASHES

Algorithmic Search for Harmonic Extraction and Simplification

- Rule-based algorithm proposed by Prof. Lucas Wong
- Search for the possible existence of triads in every time unit, and try merging them

Observation & Strategy

- In homophonic and polyphonic textures of western music, ***harmony*** always govened by chords
- 7^{th}-***chords*** are formed by triads
- ***triads*** are formed by ***intervals***

➔ search for the possible existence of triads in every time units, and

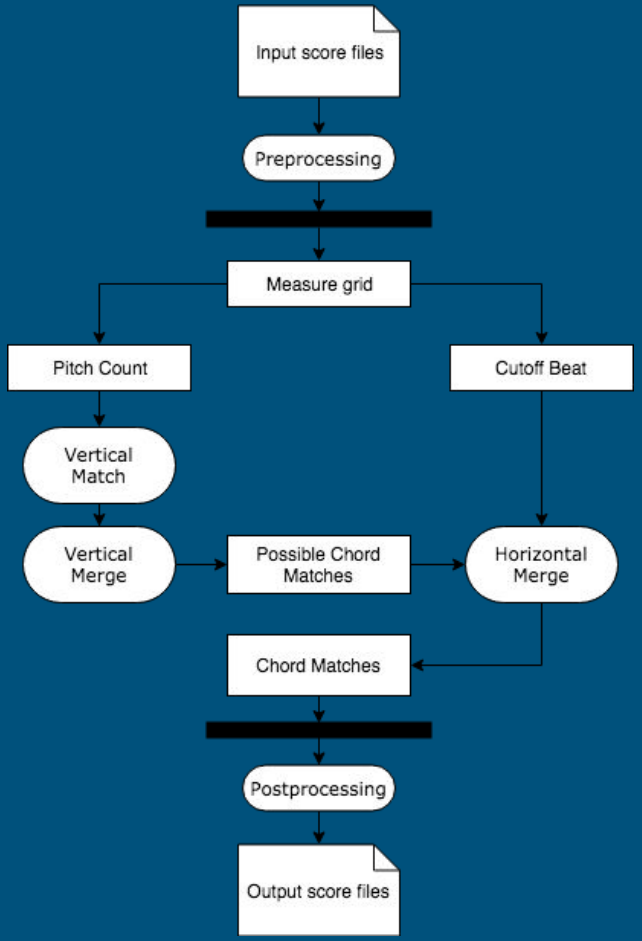
➔ perform chord merging and selection afterwards

	Triad formed by root, third and fifth	Triad formed by third, fifth and seventh
Major 7^{th}	Major triad	Minor triad
Minor 7^{th}	Minor triad	Major triad
Dominant 7^{th}	Major triad	Diminished triad
Diminished 7^{th}	Diminished triad	Diminished triad
Half-dimished 7^{th}	Diminished triad	Minor triad

	Intervals between root & third	Interval between third & fifth
Major triad	Major 3^{rd}	Minor 3^{rd}
Minor triad	Minor 3^{rd}	Major 3^{rd}
Diminished triad	Minor 3^{rd}	Minor 3^{rd}
Augmented triad	Major 3^{rd}	Major 3^{rd}
Italian-6 triad	Diminished 3^{rd}	Major 3^{rd}

Work Flow

1. Preprocessing
   - measure grid
   - pitch counter
2. Vertical Match
3. Vertical Merge
   - possible chord matches
4. Horizontal Merge
   - final matches
5. Postprocessing
   - output chord labels to musicXML



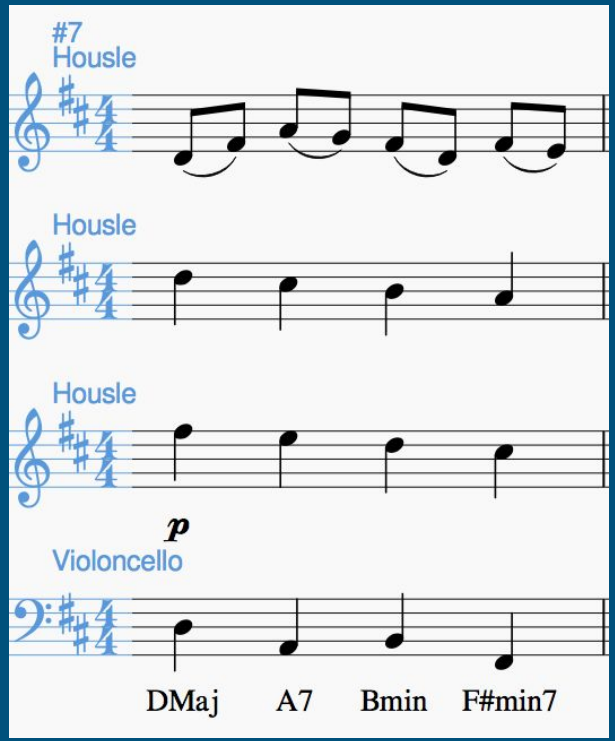
Step1:

1. Preprocessing
    - functions similar to last semaster
        - voice to parts, slicing notes with the smallest time unit
    + Rests substitution
        + notes tends to sustain and substiude rests in human ears
    + Generate a pitch counter for the next step

Step2: Grid illustration (Canon in D, m7)

2. Vertical Match: search for the possible existence of triads in every time units,

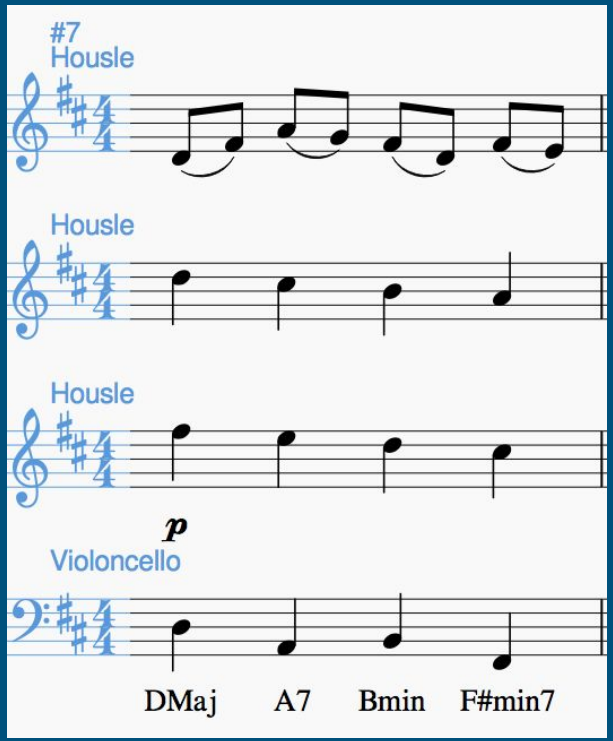
D	F#	A	G	F#	D	F#	E
D	D	C#	C#	B	B	A	A
F#	F#	E	E	D	D	C#	C#
D	D	A	A	B	B	F#	F#
triad (D, F#)	triad (D, F#)	AMaj	AMaj C#dim	Bmin	triad (B,D)	F#min	F#min AMaj



Step3: Grid illustration

3. Vertical Merge: perform 7th chord merging for multiple vertical matches

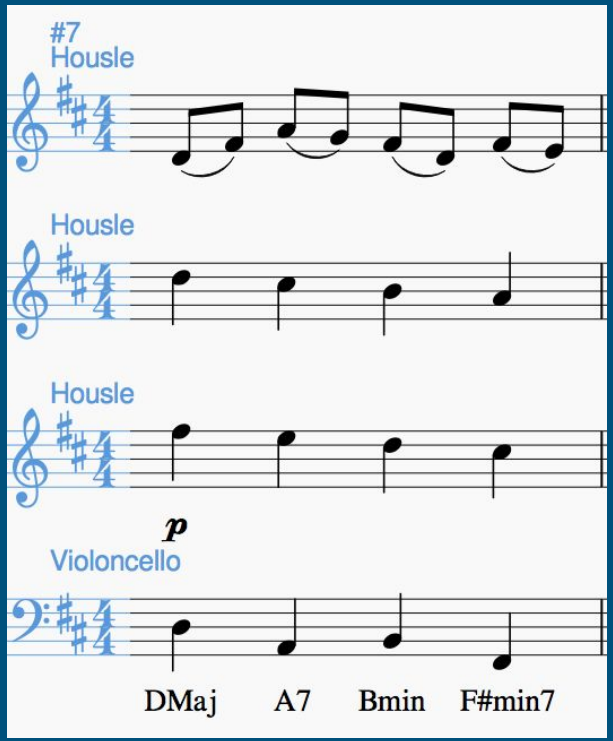
D	F#	A	G	F#	D	F#	E
D	D	C#	C#	B	B	A	A
F#	F#	E	E	D	D	C#	C#
D	D	A	A	B	B	F#	F#
triad (D, F#)	triad (D, F#)	AMaj	A7	Bmin	triad (B,D)	F#min	F#min 7



Step4: Grid illustration

4. Horizontal Merge: maximise the chord selection results by checking for possible merges between beat

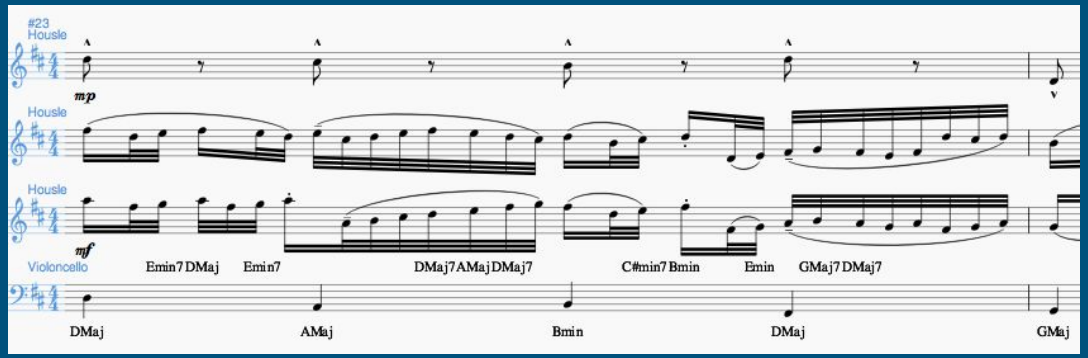
D	F#	A	G	F#	D	F#	E
D	D	C#	C#	B	B	A	A
F#	F#	E	E	D	D	C#	C#
D	D	A	A	B	B	F#	F#
DMaj		A7		Bmin		F#min7	



Pros & Cons

✔ no need to deal with key changes

✘ overfitting always happens
running notes of different parts form harmony



excerpt from Canon in D m23

https://musescore.com/user/26369751/scores/5067808
https://musescore.com/user/26369751/scores/5067822

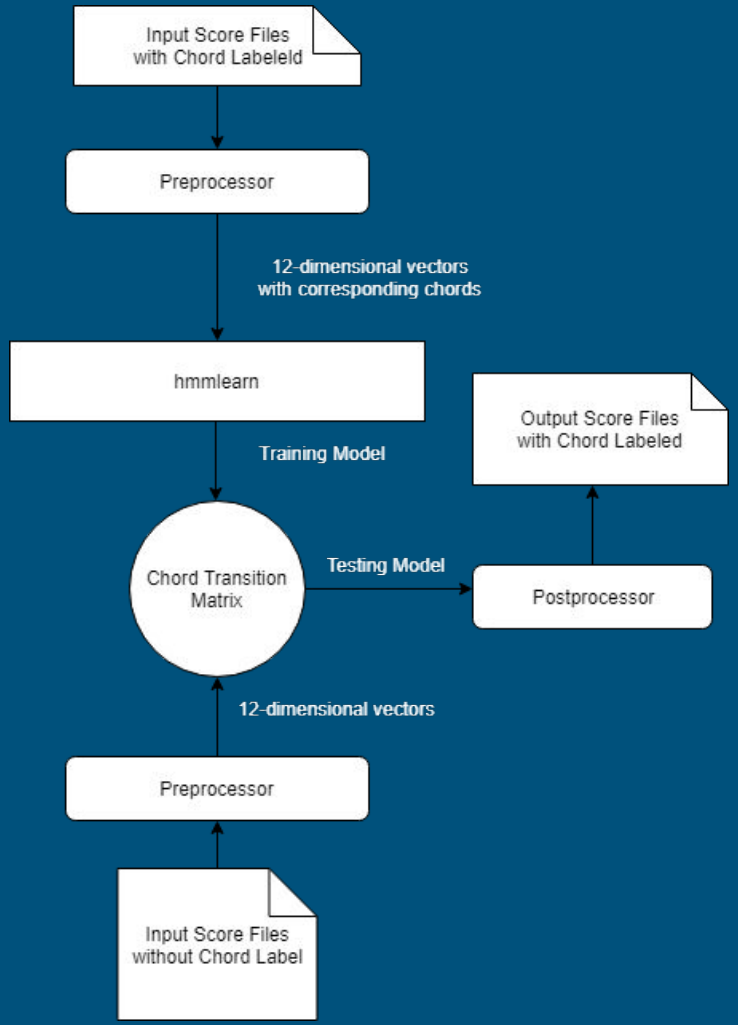
Hidden Markov Model

Machine Learning Approach to Find how Chords Transit

- Machine learning approach suggested by Professor Wong
- Generating the chord transition martix and use it to predict how chords transit

Work Flow

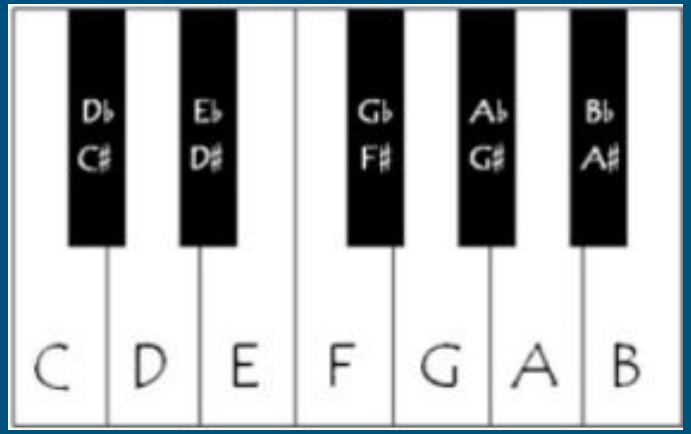
1. Collecting Training Data and Testing Scores
2. Preprocessing Training Data
3. Training Model
   - EM Algorithm
4. Preprocessing Testing Data
5. Testing
   - Viterbi Algorithm
6. Postprocessing



Model Design -- Input Format

- A chromatic scale is consisted of 12 pitches

- Two adjacent pitches have a difference of one semitone



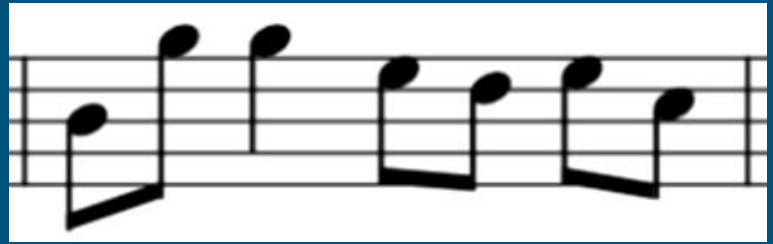
12-Pitches in an Octave

Model Design -- Input Format

Note	C	C#/Db	D	D#/Eb	E	F	F#/Gb	G	G#/Ab	A	A#/Bb	B
Dimension	1	2	3	4	5	6	7	8	9	10	11	12

A Table Showing how Pitches and Dimensions are Correlated

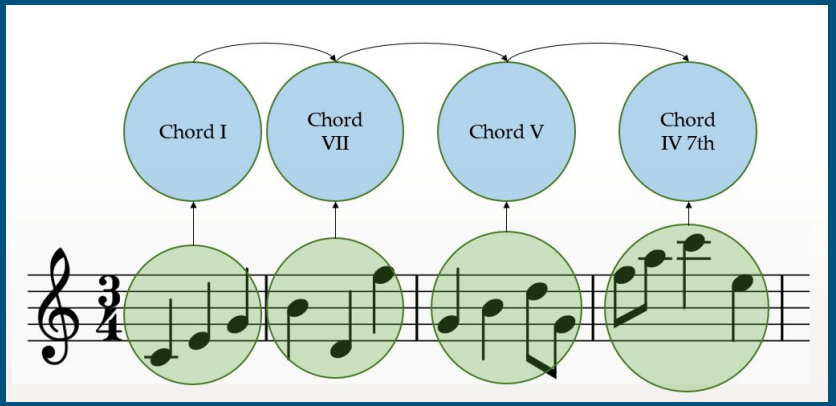
- In a certain time unit, if a pitch exists then we assign it 1.
- Otherwise, assign it 0.



$$yt=[1,0,1,0,0,0,0,1,0,0,0,1]$$

Model Design -- Hidden States

- Chords are represented as Hidden States in our model, corresponding to the notes in every single time units.



Graph Illustration in C major

- Separate chord transition matrix for separate keys.

Model Design -- Hidden States

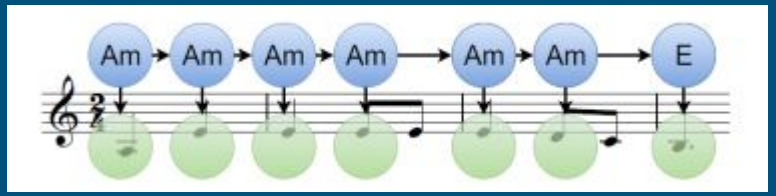
List of Keys Appeared in Training Data:

- Major Keys: C, D, E, Eb, F, G, Ab, Bb
- Minor Keys: C, D, F, G, A

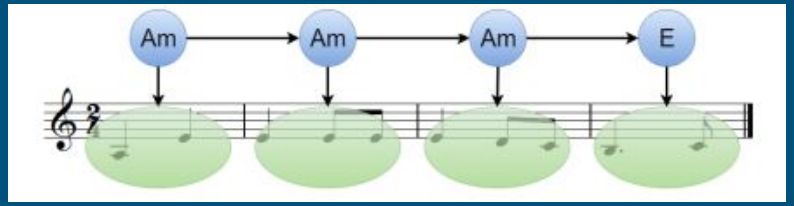
List of Chords Appeared in Training Data:

- I, I+, IIb, II, II7, III, IV, V, V7, V+, V+7, VIb, VI, VIGer, VII, VII7, VIIGer, VIIIta, VIIdim, VIIdim7

Model Design -- Time Unit



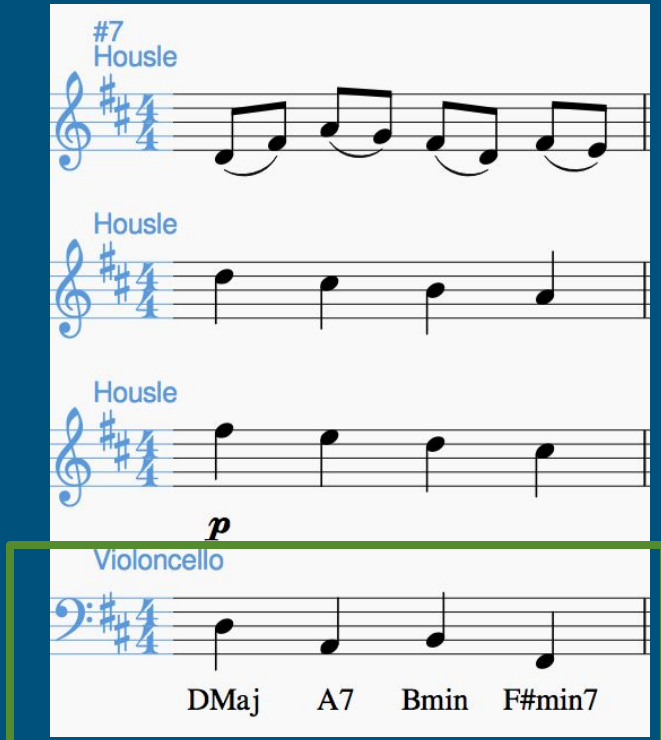
Every Single Beats? → Overfit



Measure? → Missing Chord Change

Model Design -- Time Unit

- Current approach: slowest moving part governs chord changes
  - Finding lowest moving part of each measure
    1. slowest movement
    2. lowest average pitch
  - movement of lowest moving part -> time unit



Model Design - Emission Probability

Main Approach: Degree of Similarity

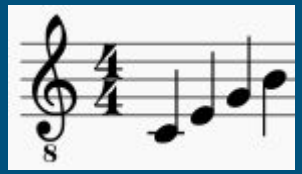
- Lowest Note Match: +5
- Second Lowest Note Match: +3
- Third Lowest Note Match: +2 (+1 for 7th chord)
- 7th Note Match: +1 (for 7th chord)
- Other Notes Occuring: -1

Model Design - Emission Probability

- deg(sim) = 10 → 10/55
- deg(sim) = 9 → Sharing the probability of 9/55
- deg(sim) = 8 → Sharing the probability of 8/55
- deg(sim) = 7 → Sharing the probability of 7/55
- deg(sim) = 6 → Sharing the probability of 6/55
- deg(sim) = 5 → Sharing the probability of 5/55
- deg(sim) = 4 → Sharing the probability of 4/55
- deg(sim) = 3 → Sharing the probability of 3/55
- deg(sim) = 2 → Sharing the probability of 2/55
- deg(sim) = 1 → Sharing the probability of 1/55
- deg(sim) = 0 → 0

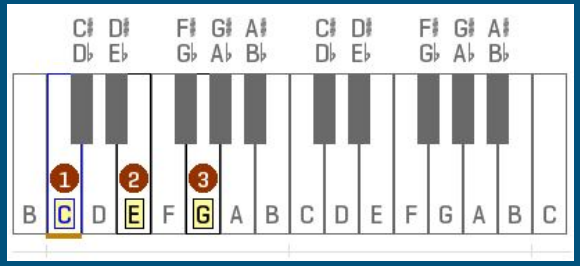
Model Design - Emission Probability

- We have a vector of [1,0,0,0,1,0,0,1,0,0,0,1], that is a list of notes including C, E, G and B

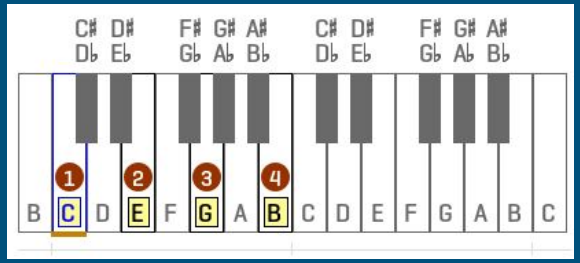


- In C major Chord I, it has 9 degree of similarity, thus get assigned the emission probability of (9/55)/9, since there are totally 9 cases sharing deg(sim) = 9.

- In C major Chord I 7th, it has 10 degree of similarity, thus the emission probability would be 10/55.



C Major Chord I

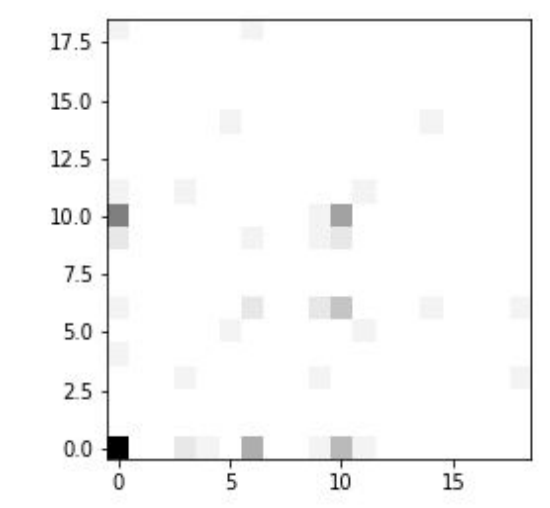


C Major Chord I 7th

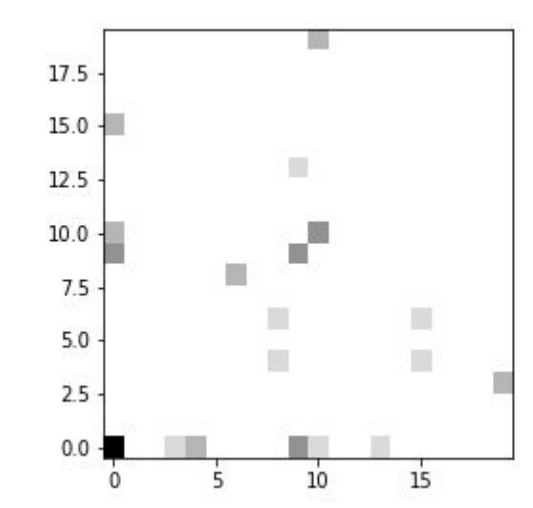
Training Data Preparation

- Beethoven Symphony No. 1 1st Movement (111 Chord Events, mainly C Major and G Major)
- Beethoven Symphony No. 5 1st Movement (122 Chord Events, mainly C Minor, Eb Major and Bb Major)
- Mozart Symphony No.25 The Little G minor Symphony - 1st Movement (214 Chord Events, G Minor)

Chord Transition Matirx Visulization

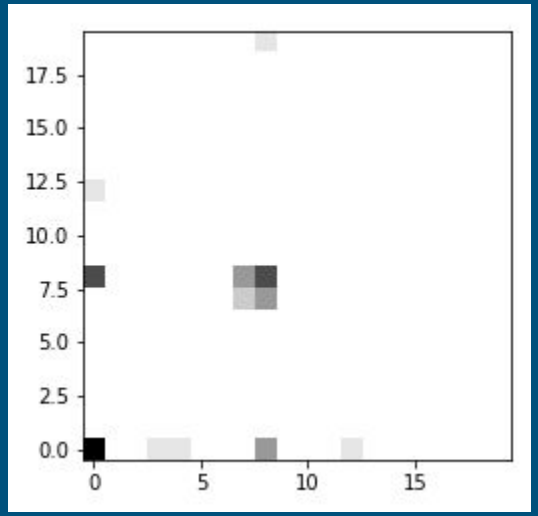


G Minor



C Minor

Chord Transition Matirx Visulization



C Major

Lack of Data

Testing

Total excerpts: 3

Total chord events: 487 (ASHES)

Total chord events: 377 (HMM)

Correctness

	ASHES	HMM
Pachelbel, Johann Canon in D	65% (soft: 89%)	38% (soft: 46%) (Lack of D major training data)
Mozart concerto K.314	63% (soft: 90%)	56% (soft: 82%)
Beethoven symphony OP.67	80% (soft: 83%)	83% (soft: 86%)

Overall	69% (soft: 87%)	58% (soft: 76%)

soft: excluding overfitting chords in the calculation of correctness

Conclusion

Possible Improvment

1. Better Approach to Define Time Unit
- Short time unit → overfit
- Long time unit → missing harmonic change

2. Hard to Find Training Data
- Certain chord transition patterns in certain keys are missing
- Pattern missing in training data -- 100% wrong result during testing

Possible Improvment

3. Key Analysis Before Applying HMM

- Key change could only be indicated by sharp/flat change
- Without key analysis, we could only do testing on pieces without key change

Q&A