Meter Identification of MIDI Using Pattern Detection

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Goal

Meter identification is the organisation of the beats of a given musical performance into a **metrical structure**, a tree in which each node represents a single note value. The children of each node divide its note into some number of equal-length notes (usually two or three), where every node at a given level must have an equal value.

The task is an integral component of **Automatic Music Transcription**, specifically when attempting to identify the time signature of a given performance. The metrical structure must be properly aligned in phase with the underlying musical performance so that the root of the tree corresponds with a logical musical segment, often a bar.

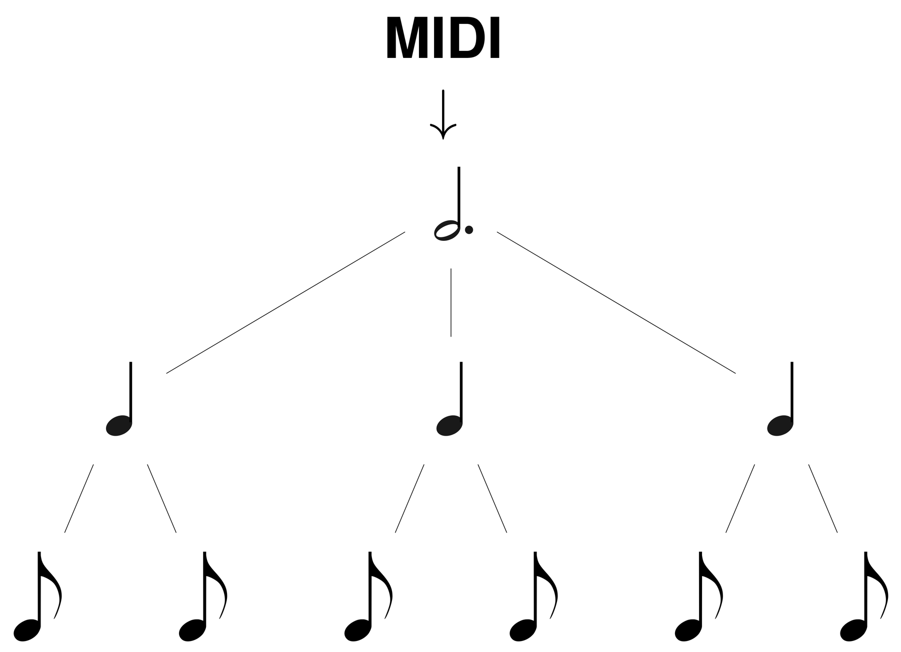

Figure 1: *The end goal of this work, to generate a metrical structure from MIDI input. The structure shown here is that of a single **3/4** bar.*

Existing Work

- Most methods look for a regular pattern of beat length deviations and beat salience, for example, Cemgil et al. [1].
- Longuet-Higgins and Steedman [2] found that certain rhythmic patterns are more likely to occur at certain levels of the metrical structure, and can therefore be used to infer the meter of a song.
- Steedman [3] continued the work, noting that repeated patterns of notes are often found at identical levels of the beat hierarchy.

Proposed Method

- Use a dictionary of **patterns**, each of which matches a segment of MIDI if it occurs at least twice in a row within that segment. Segments are taken from a single voice.
- Each pattern consists of one or more **constructs**, each of which is assigned a minimum and maximum match-length:
  - **Duration Match**—Any segments of identical length.
  - **Exact Match**—Any segments containing notes of identical pitch and value.
  - **Rhythmic Match**—Any segments containing notes of identical rhythm and value, and an optional **interval match**:
    - **Identical**—The intervals between notes in each segment are of identical direction and magnitude within a 50% semitone error.
    - **Opposite**—The intervals are of opposite direction, and magnitude within a 50% semitone error.
    - **None**—Any interval directions and magnitudes are acceptable.
- To identify a performance's metrical structure based on its pattern matches, the matches are combined together and metrical trees are ranked by the number of pattern matches which it fits. A metrical tree fits a pattern match if and only if that match would fall exactly within a single node of the tree.

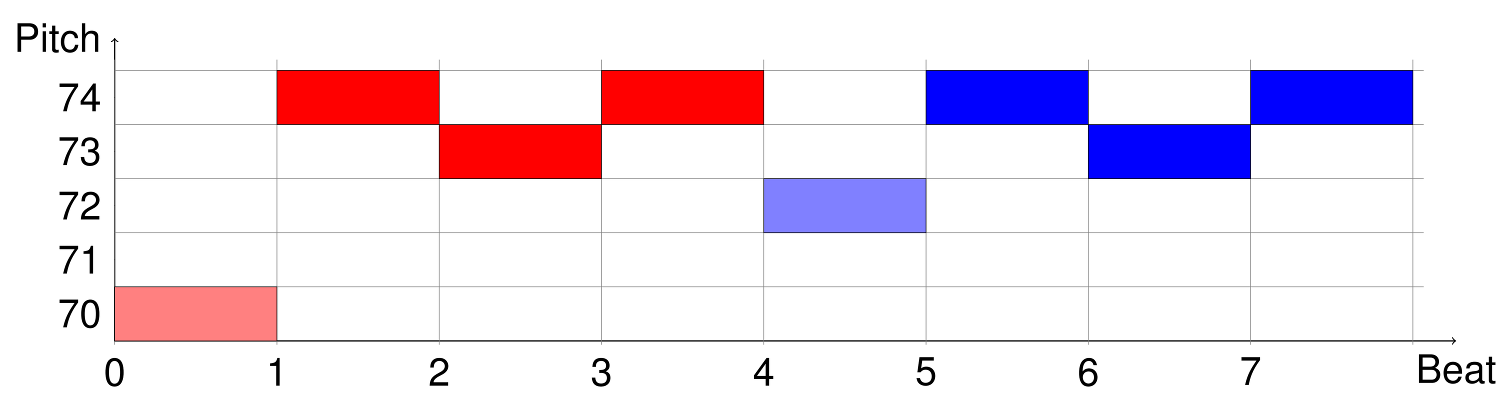

Figure 2: *A match of a pattern containing a 1 beat **duration match** (light shades) followed by a 3 beat **exact match** (dark shades).*

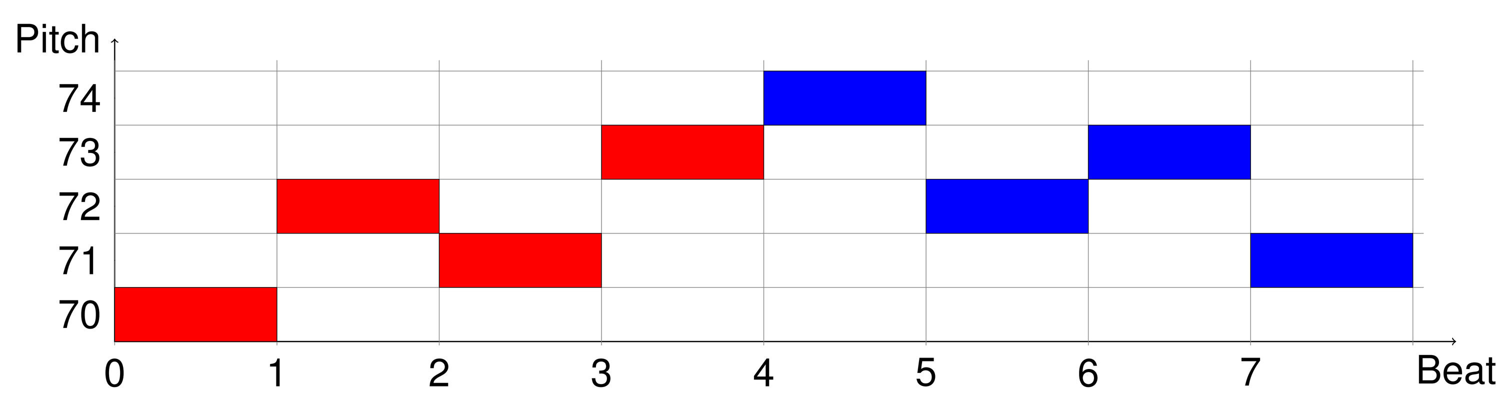

Figure 3: *A match of a pattern containing only a 4 beat **rhythmic match** with a **opposite** interval match.*

Preliminary Results

- Dictionary used:
  1. An **exact match** of 4 to 48 beats.
  2. A **rhythmic match** of 4 to 48 beats, with a **identical** interval match.
  3. A **duration match** of 2 to 4 beats, followed by an **exact match** 1 to 7 times as long.
  4. A **duration match** of 2 to 4 beats, followed by a **rhythmic match** 2 to 4 times as long, with a **identical** interval match.
- Corpus: computer-generated MIDI of the 48 fugues from Bach's Well-Tempered Clavier. These files are already separated into voices and beat-aligned, and we take a beat to be the length of a 32nd note.

Rank	Accuracy
Top 1	45.8%
Top 3	68.8%
Top 5	79.1%
Top 10	**85.4%**
Steedman	77.1%

Table 1: *The percentage of the fugues whose meter's correct structure was found somewhere within the given ranking of metrical structures hypotheses, compared with the results from Steedman [3].*

Book I						Book II					
Fugue	**Rank**	**Fugue**	**Rank**	**Fugue**	**Rank**	**Fugue**	**Rank**	**Fugue**	**Rank**	**Fugue**	**Rank**
1	X	9	2	17	1	1	2	9	1	17	1
2	3	10	1	18	3	2	1	10	X	18	1
3	1	11	4	19	1	3	1	11	1	19	2
4	1	12	2	20	2	4	1	12	5	20	2
5	1	13	1	21	6	5	X	13	1	21	X
6	9	14	4	22	X	6	X	14	1	22	2
7	1	15	1	23	1	7	1	15	X	23	1
8	4	16	5	24	2	8	2	16	5	24	9

Table 2: *The rank of the correct metrical structure for each fugue as predicted by the method described here. An X represents where the correct metrical structure was not in the top 10 hypotheses.*

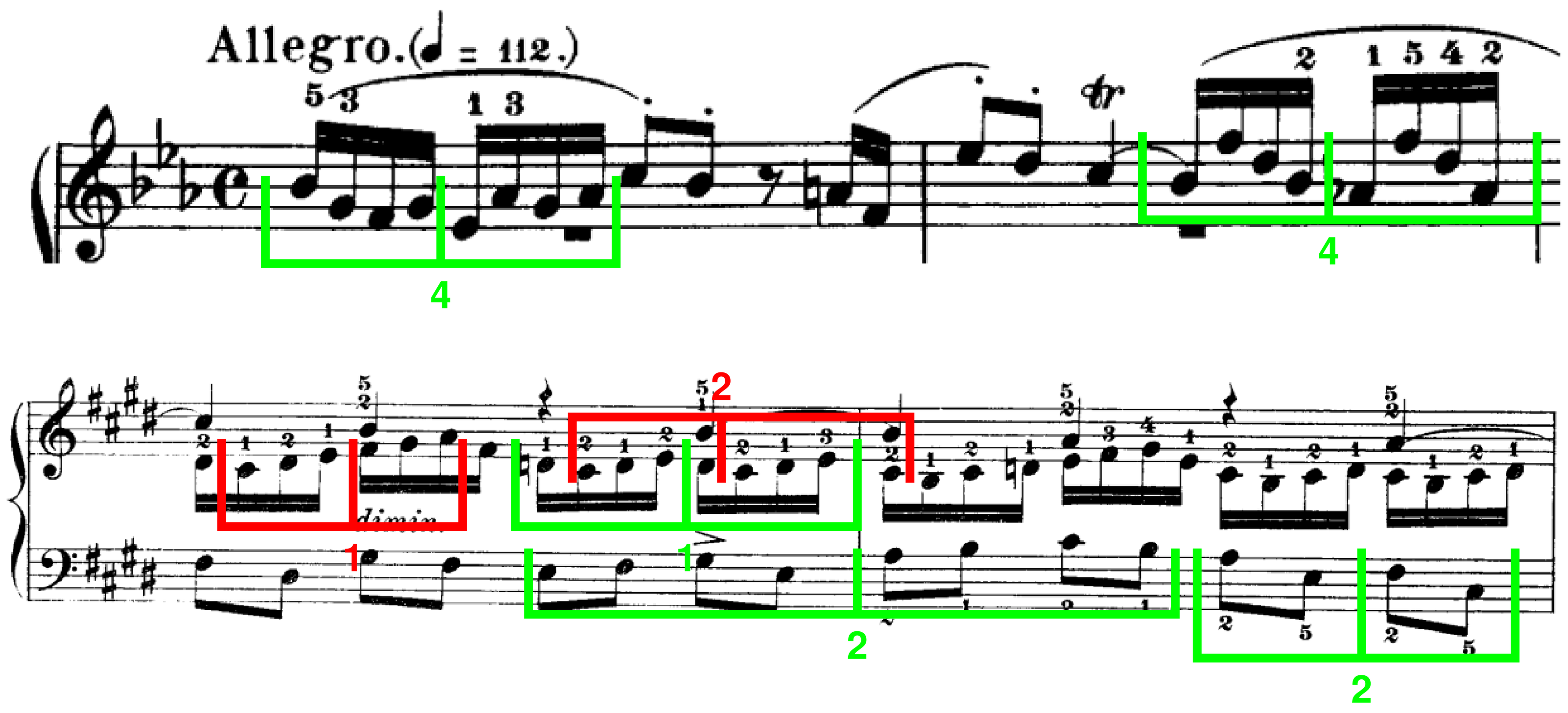

Figure 4: *An example of pattern matches from the 7th (top) and 9th (bottom) fugues from Book I of the WTC (BWVs 852 and 854). Red brackets indicate that a match doesn't fit with the proper metrical structure, while green brackets indicate a correct fit. The number indicates which pattern from our dictionary described above was used to find the pattern match. Note that all matching patterns are not shown here.*

Conclusion

- **Pattern detection can aid meter identification.**
- To do:
  - Define interval matching musically (e.g. major and minor thirds).
  - Learn dictionary of patterns from data, and weight each probabilistically.
  - Adapt to work on live MIDI input.
  - Incorporate rhythmic accent and metrical stress.
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References

[1] A. T. Cemgil, P. Desain, and B. Kappen. Rhythm Quantization for Transcription. *Computer Music Journal*, 24(2):60–76, June 2000.

[2] H. C. Longuet-Higgins and M. J. Steedman. On Interpreting Bach. *Machine Intelligence*, 6:221–241, 1971.

[3] M. J. Steedman. The perception of musical rhythm and metre. *Perception*, 6(5):555–69, Jan. 1977.