Meter Detection in Symbolic Music Using a Lexicalized PCFG

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Meter Detection

- Repeating tree structure
  - Branching factors
  - Phase
  - Tactus length

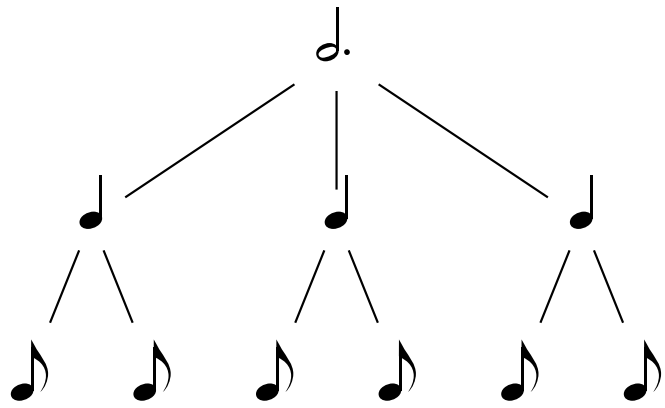

Figure: The metrical structure of a **3/4** bar.

PCFG

$S \rightarrow M_{b,s}$
$M_{b,s} \rightarrow B_s \ \ldots \ B_s$ (b times)
$B_s \rightarrow SB \ \ldots \ SB$ (s times) $\mid r$
$SB \rightarrow r$

- Condition probabilities on measure
  - $\forall b, s : p(S \rightarrow M_{b,s}) = 1$
- Problem: assumption of independence

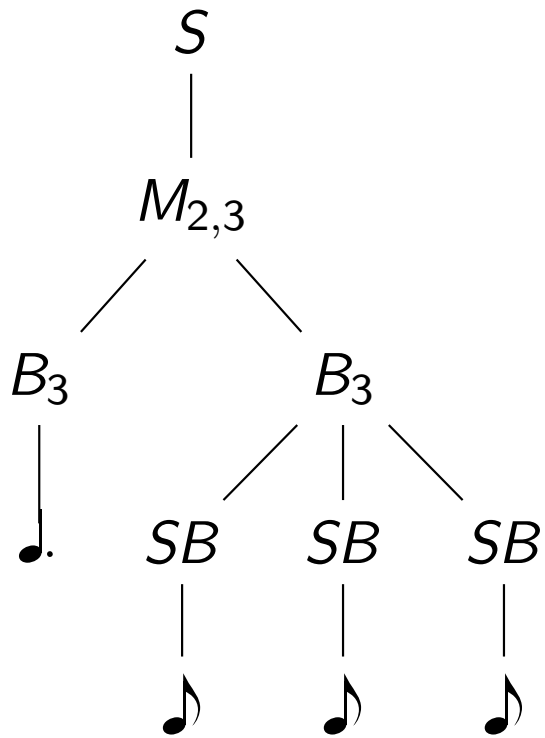

Figure: PCFG analysis of a **6/8** bar.

PCFG + Lexicalization (LPCFG)

- Add heads $(l; o)$
  - l = Note length
  - o = Note onset

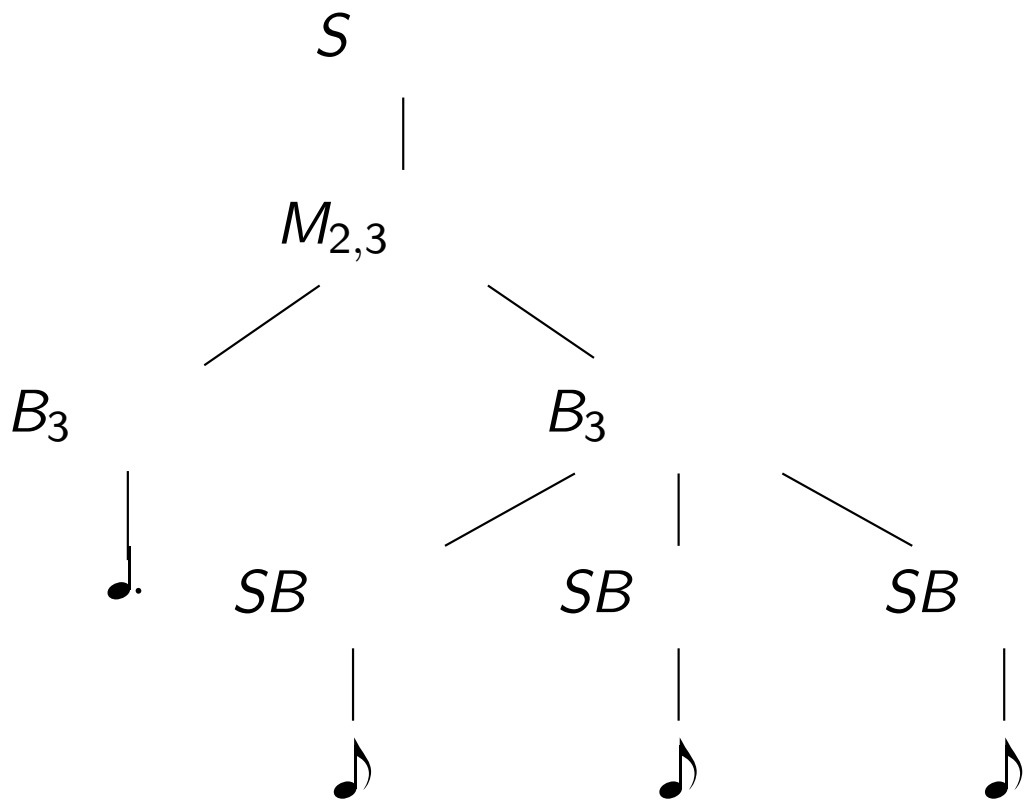

Figure: LPCFG analysis of a **6/8** bar.

- Standard LPCFG probabilities (+ measure)

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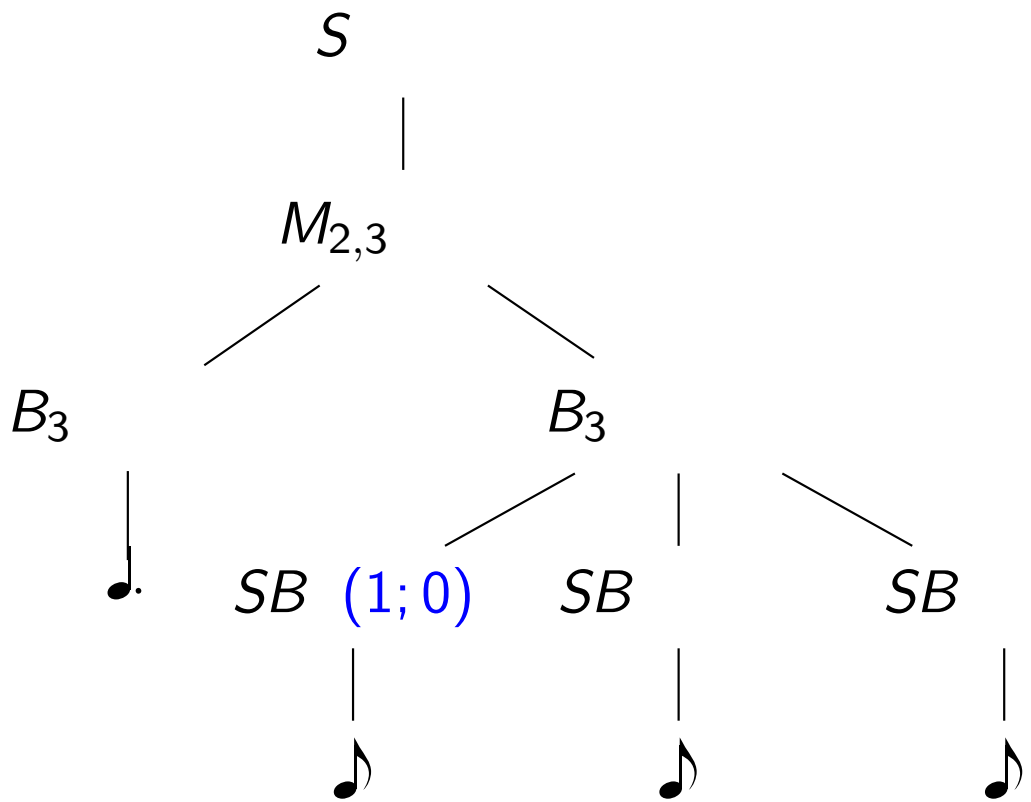

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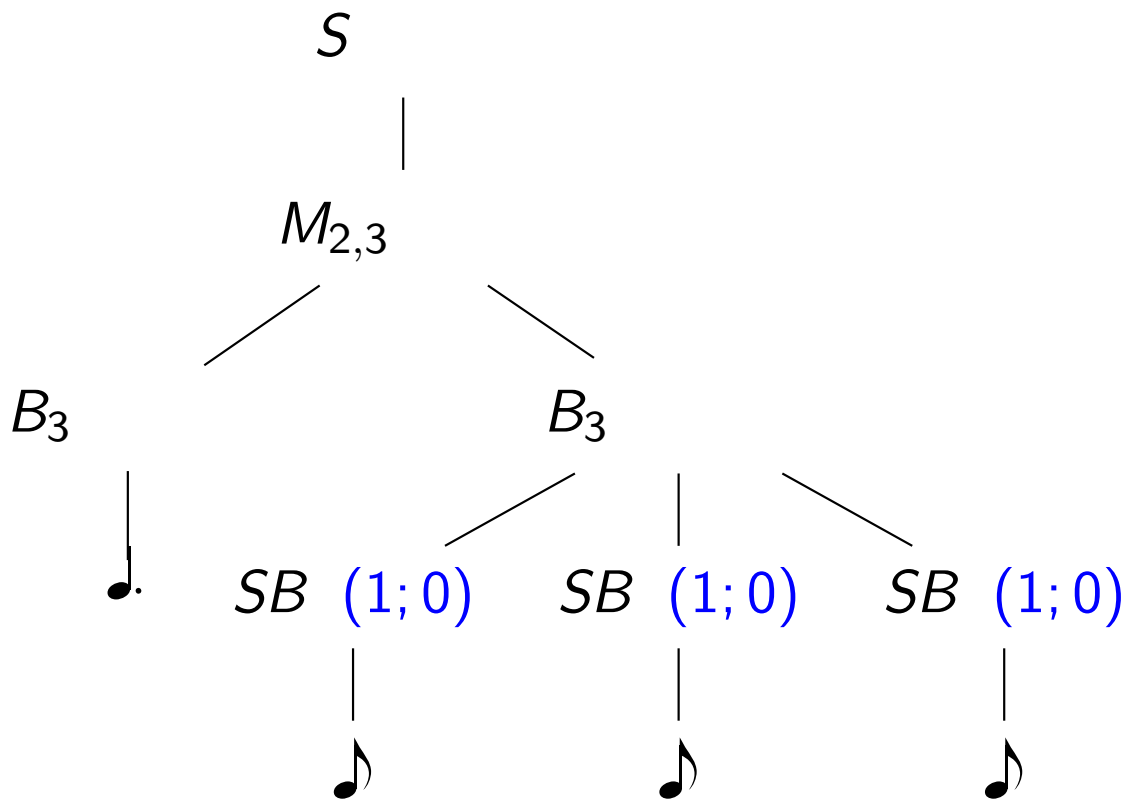

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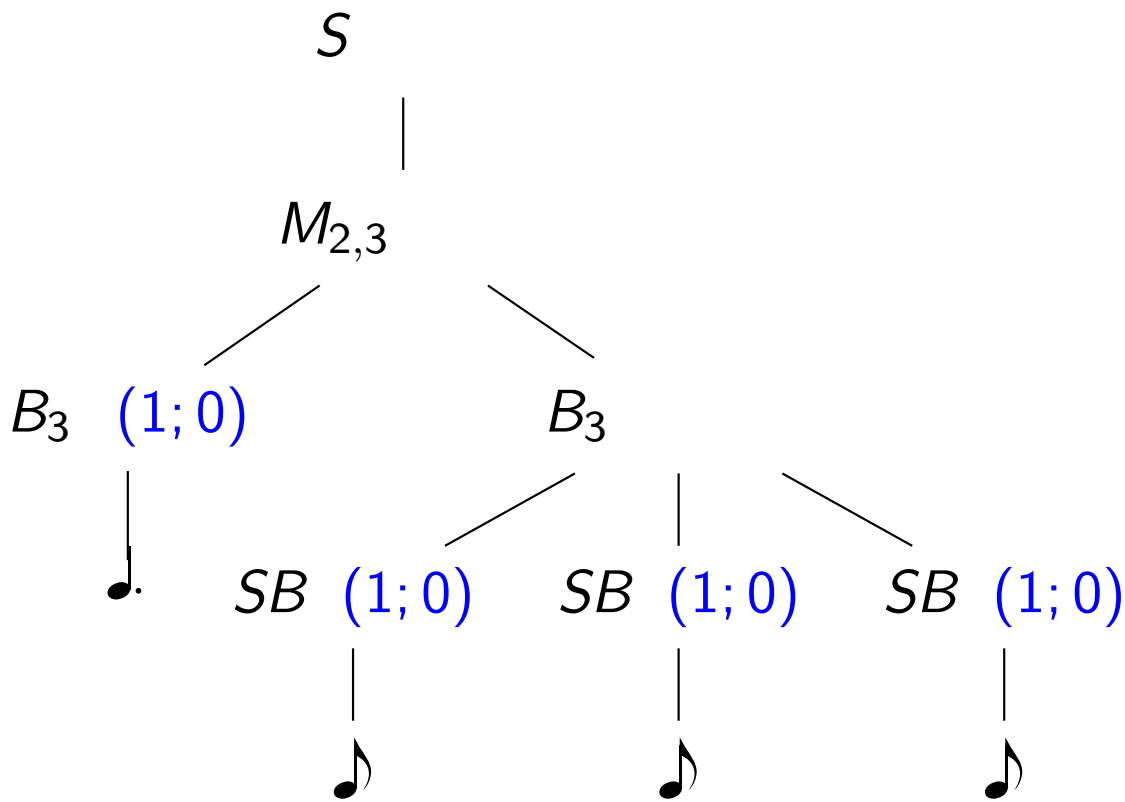

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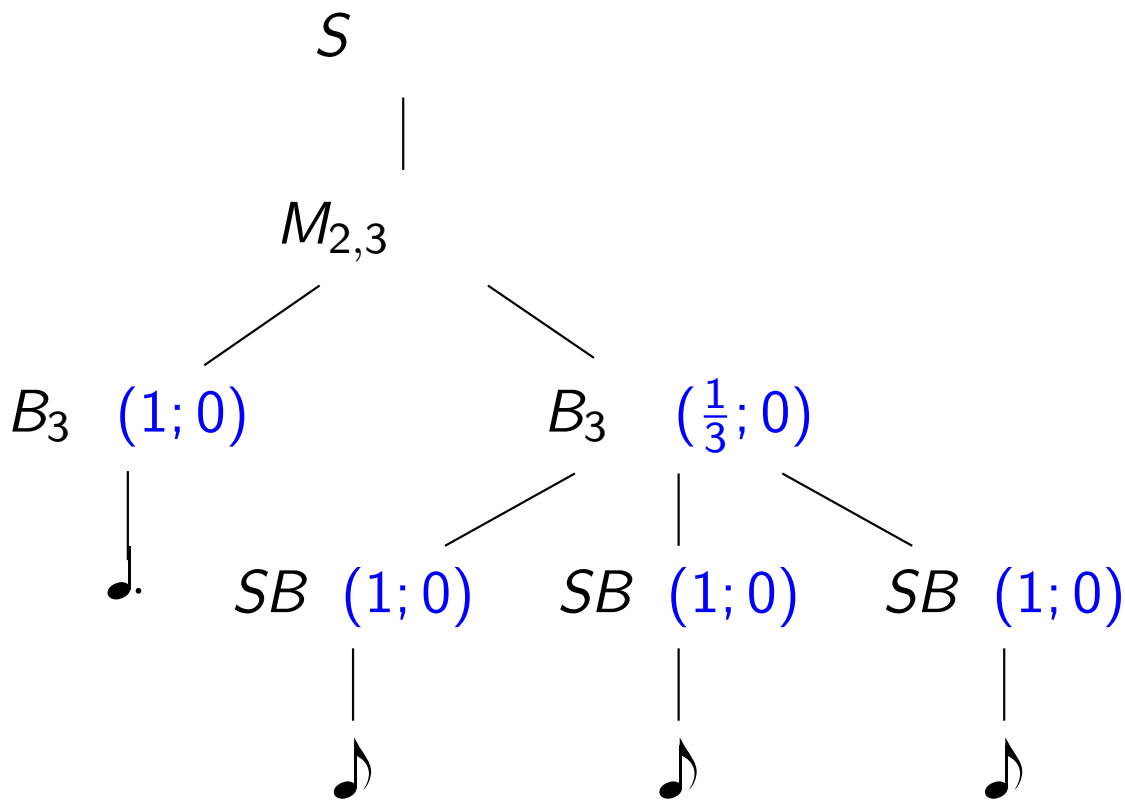

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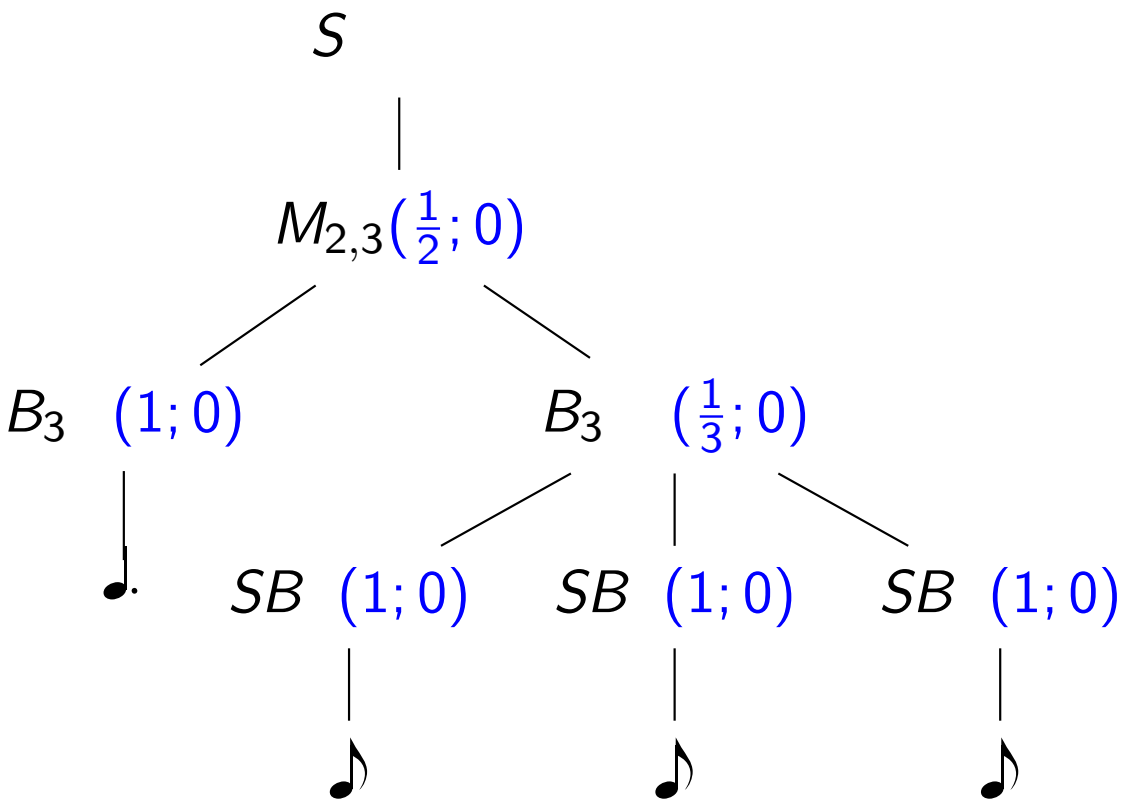

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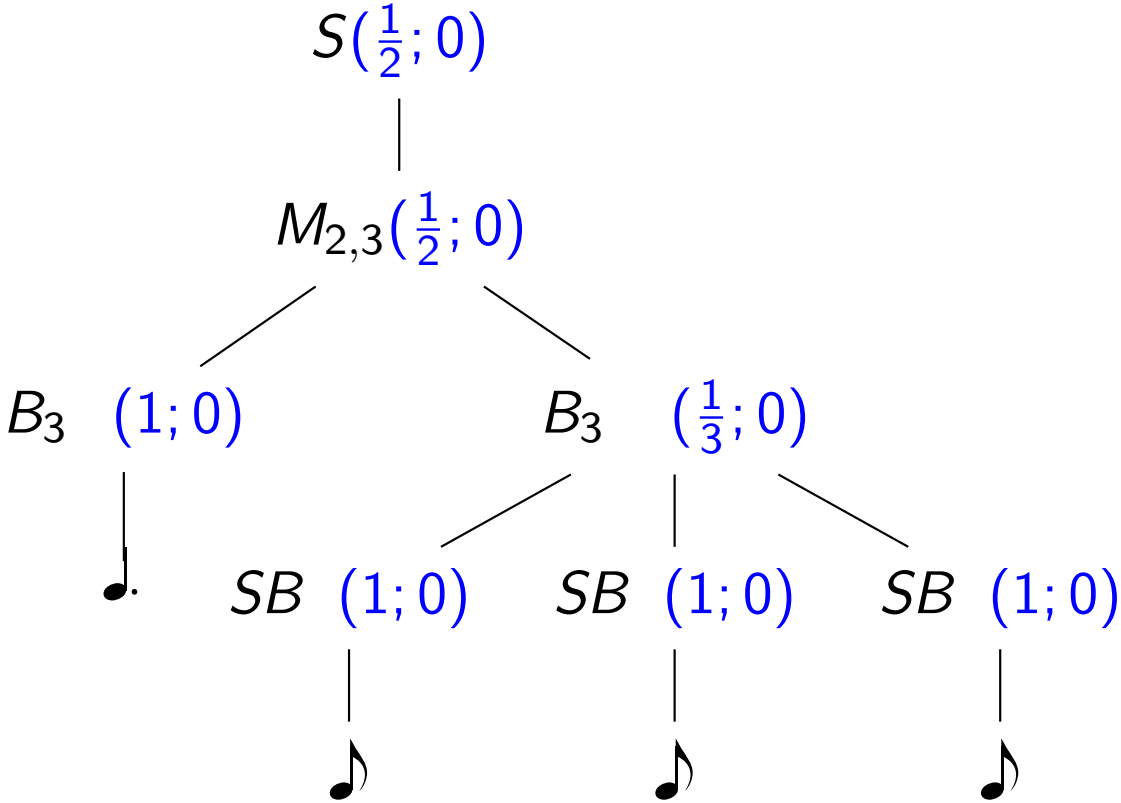

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- Add heads $(l; o)$
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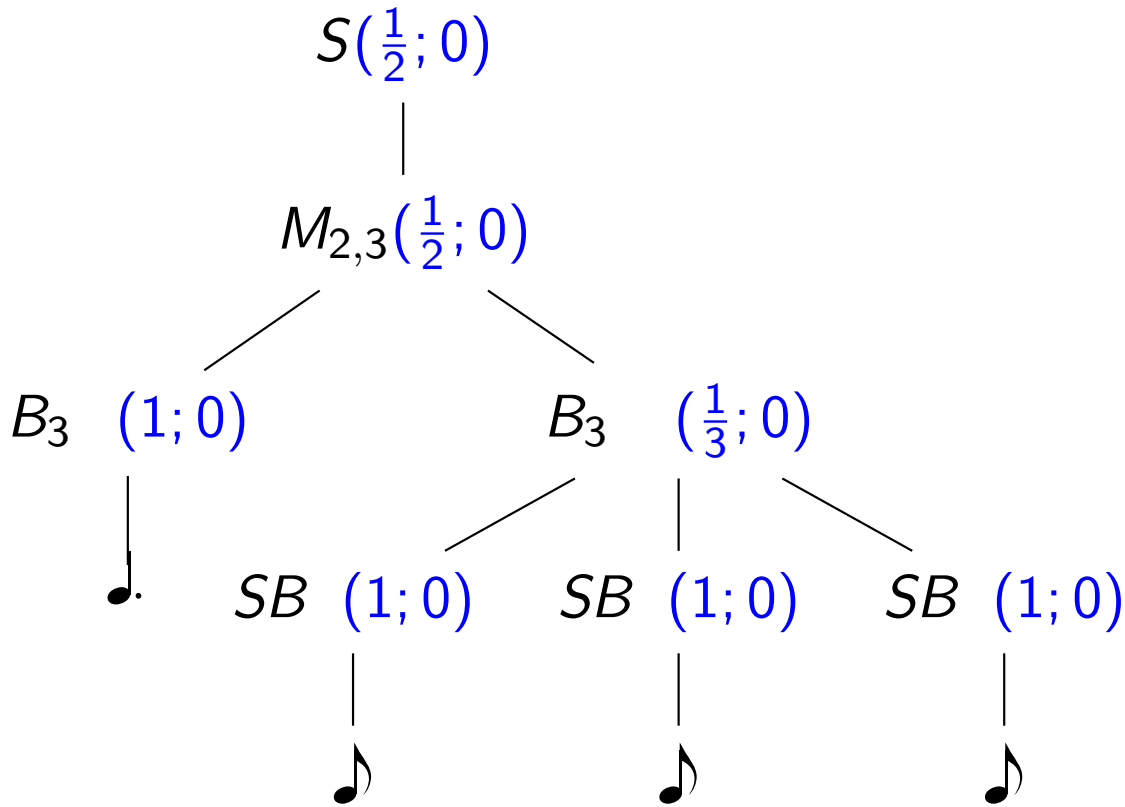
- Add strengths, based on siblings' heads
  - S = Strong
  - E = Even
  - W = Weak
- Standard LPCFG probabilities (+ measure)



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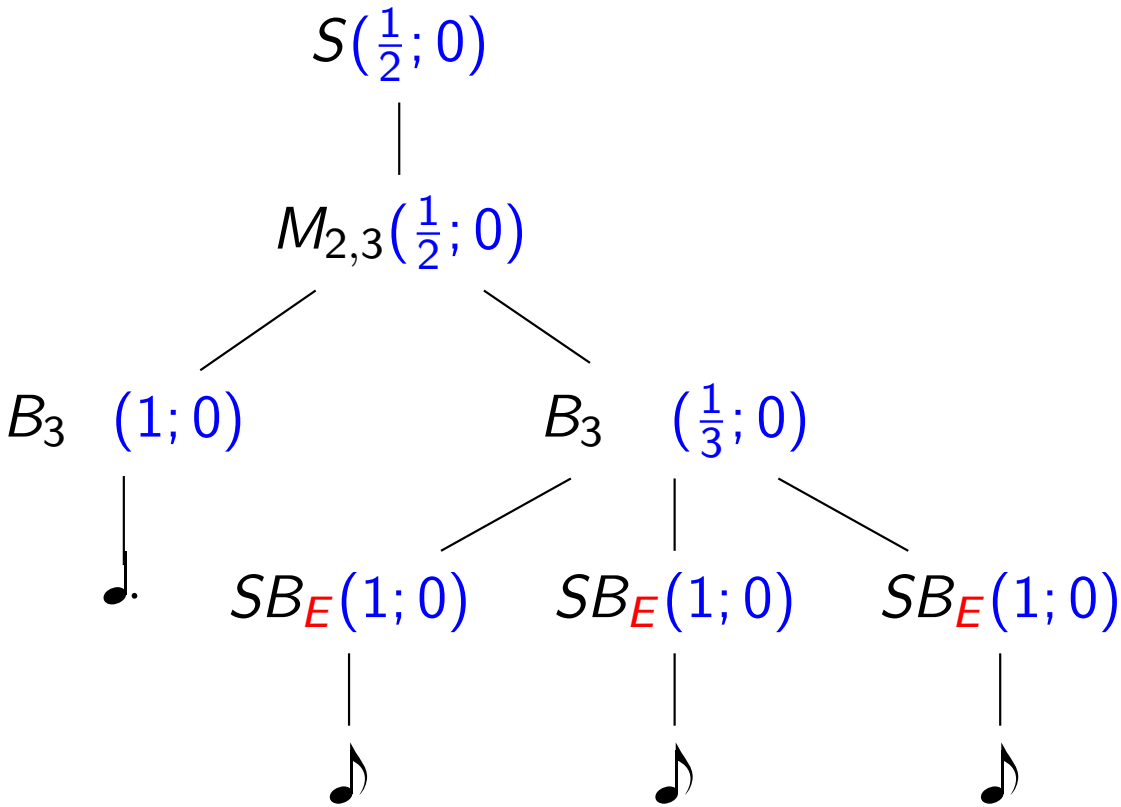

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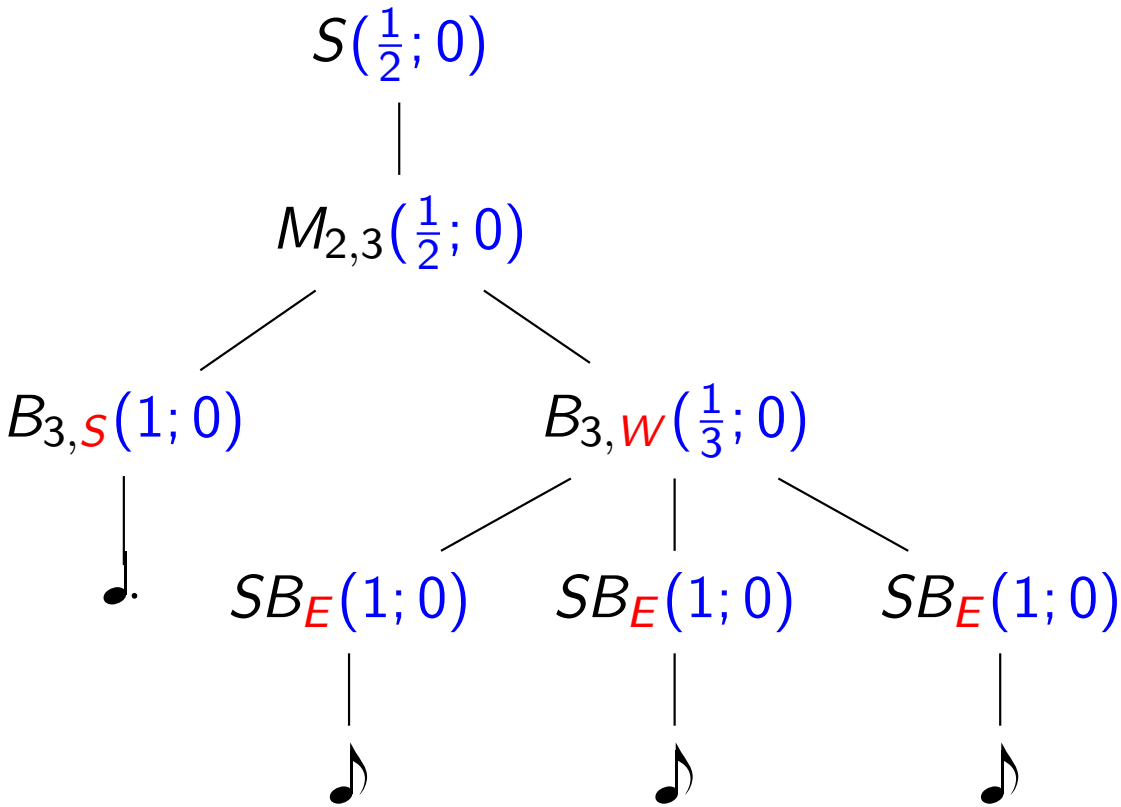

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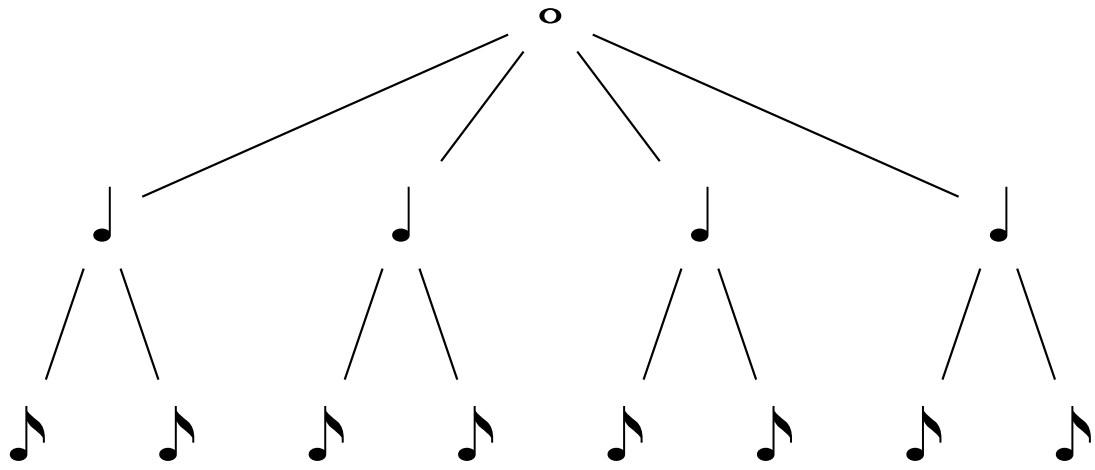
Inference

- Start many hypotheses simultaneously
- 3 latent variables:
  - Tree structure
  - Phase
  - Tactus length

- Hypotheses cannot change structure, phase, or tactus length throughout a piece

Evaluation Metric



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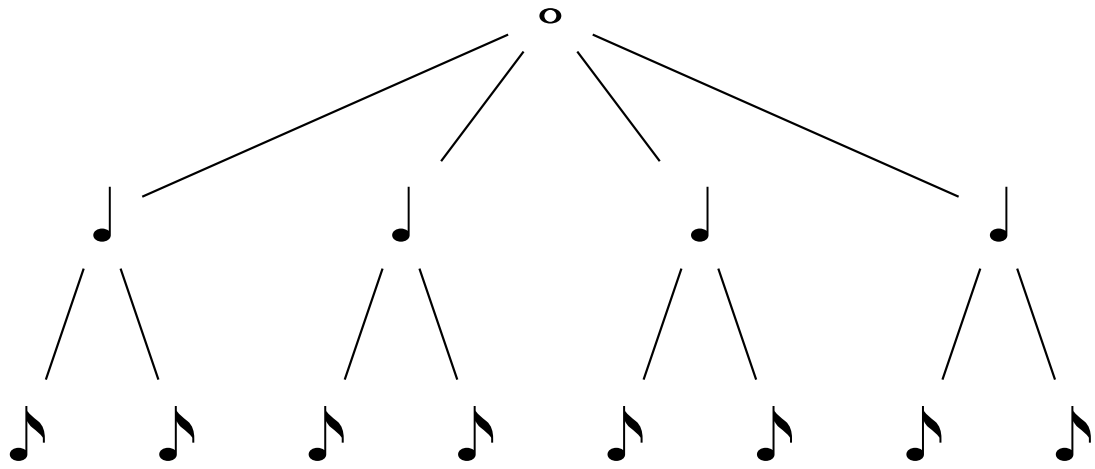
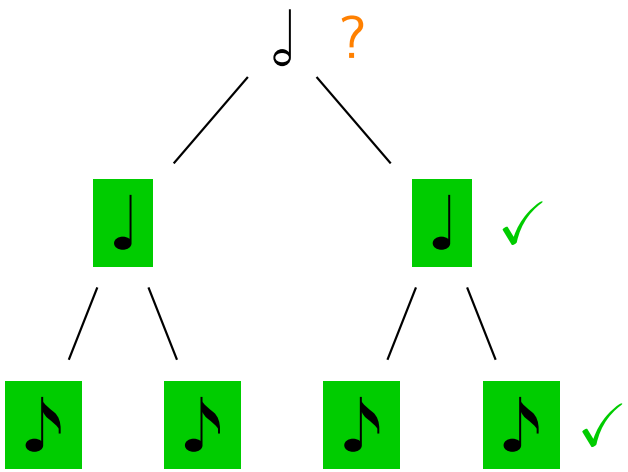
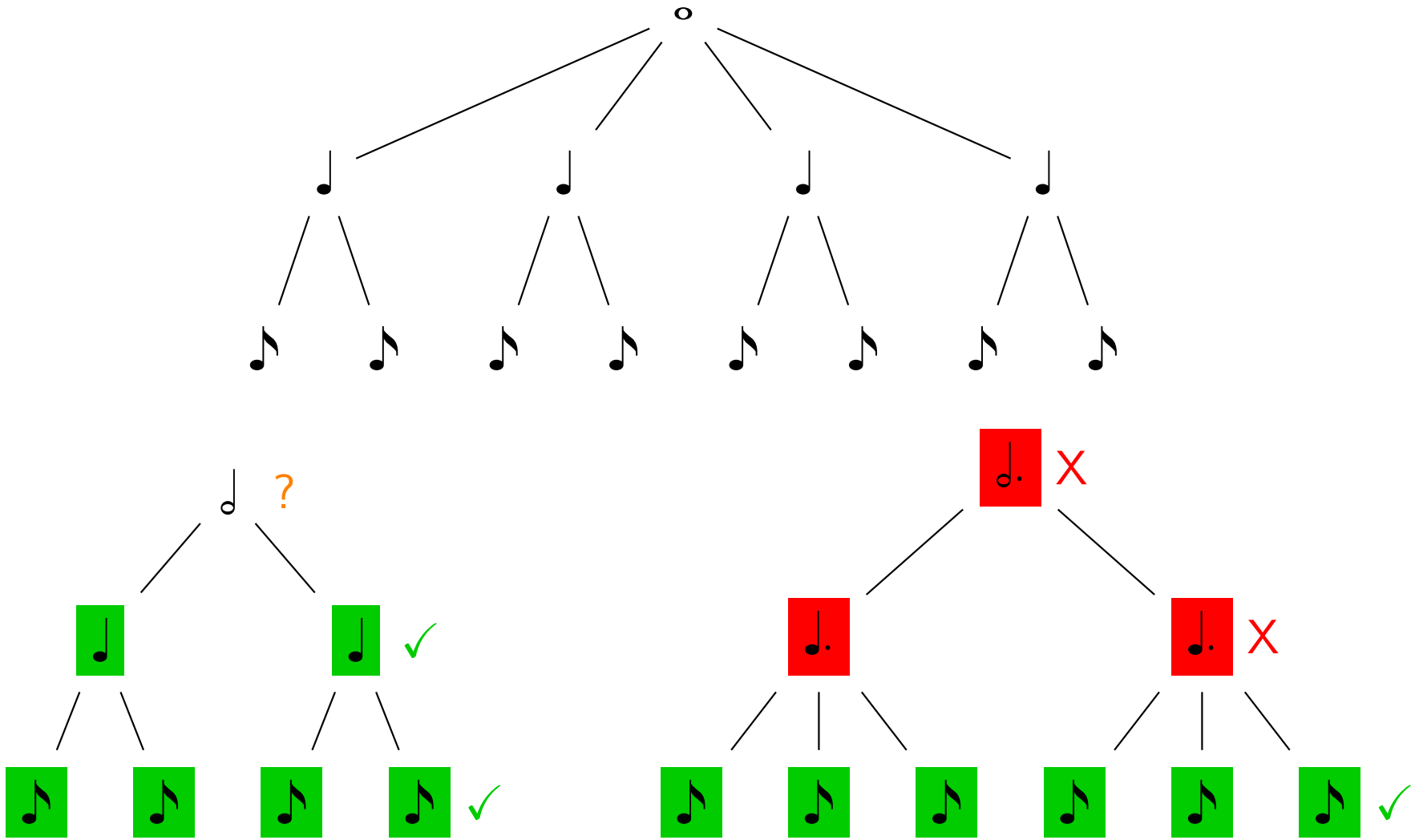




2 TP, 0 FP, 1 FN

P=1, R=0.67, F1=0.8

Evaluation Metric



2 TP, 0 FP, 1 FN
P=1, R=0.67, F1=0.8

1 TP, 2 FP, 2 FN
P=0.33, R=0.33, F1=0.33

Results 1

- Hand-aligned to the beat:

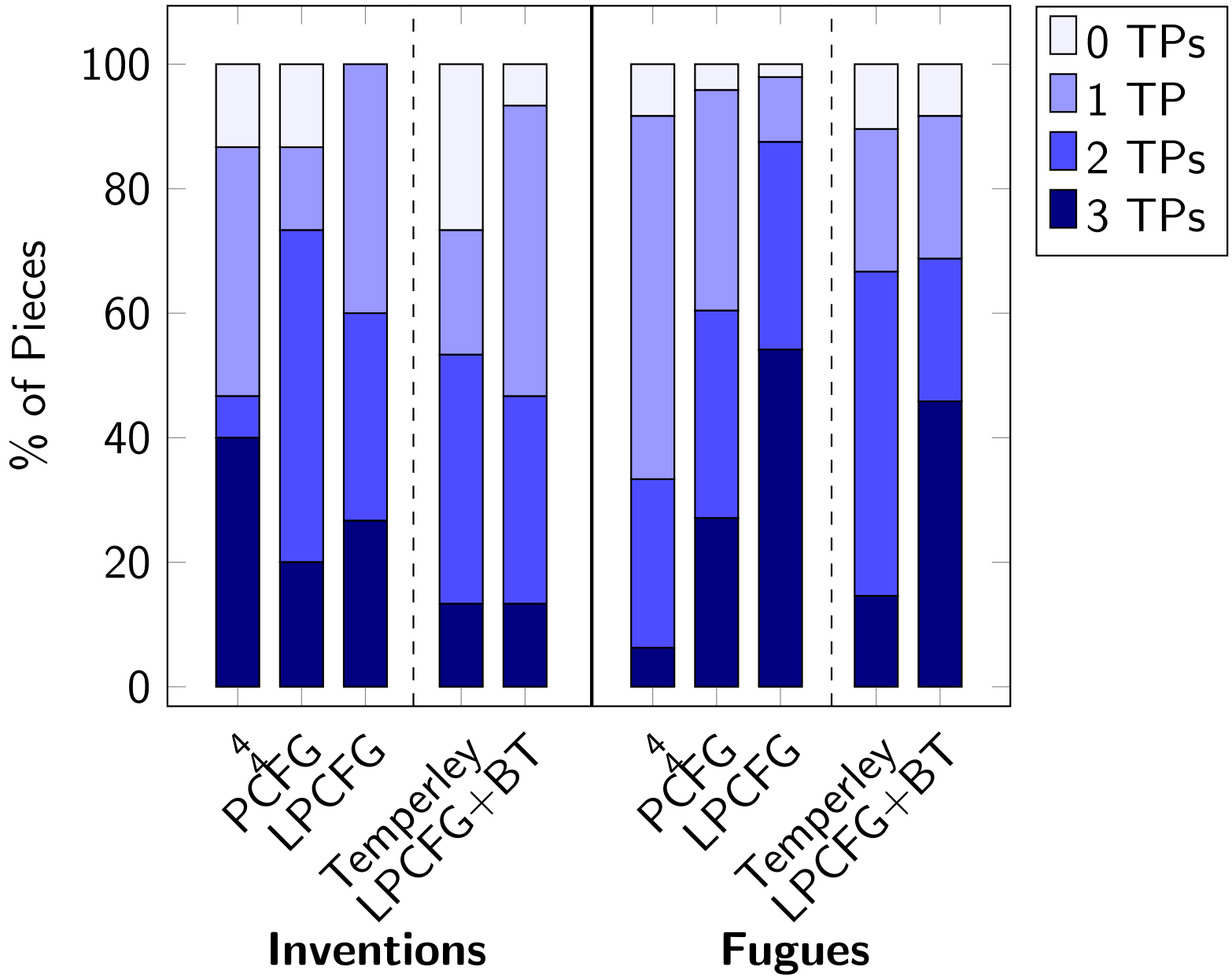
Method	Inventions	Fugues
$\frac{4}{4}$	0.58	0.45
PCFG	0.61	0.63
LPCFG	**0.63**	**0.80**

- Automatically aligned:

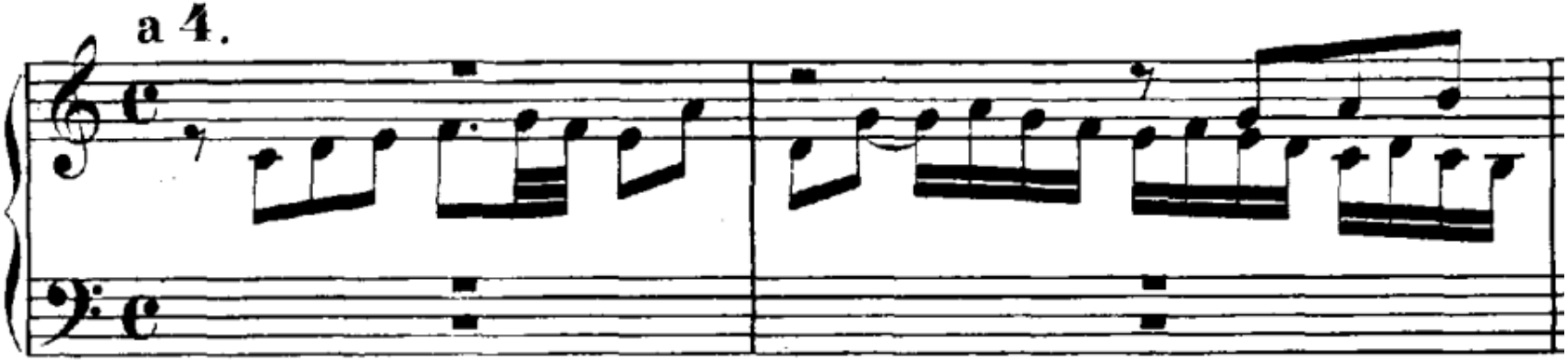
Method	Inventions	Fugues	Essen
Temperley[1]	**0.58**	0.63	0.60
LPCFG+BT	0.55	**0.72**	**0.74**

[1] Temperley, D. (2009). A Unified Probabilistic Model for Polyphonic Music Analysis. *Journal of New Music Research*.

Results 2


% of Pieces
100
80
60
40
20
0
0 TPs
1 TP
2 TPs
3 TPs
4
PCFG
LPCFG
Temperley
LPCFG+BT
Inventions
Fugues

Results 3: WTC I, Fugue I (BWV 846)

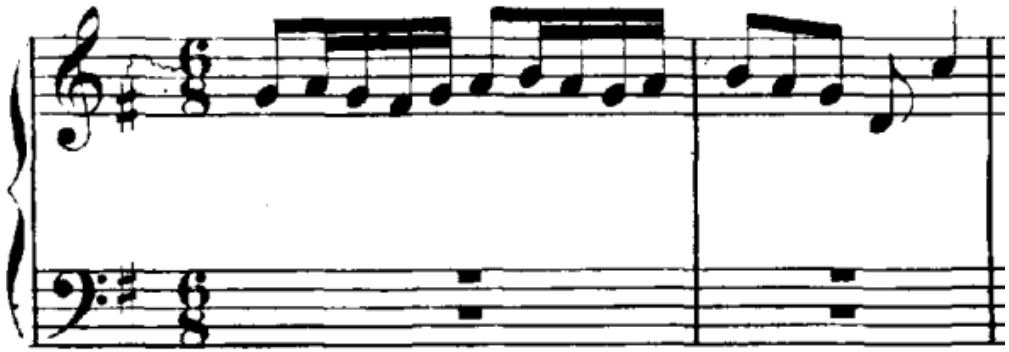


Audio

✓ 4/4 time guessed

- | W W S W | S W W W | . . .

Results 4: WTC I, Fugue XV (BWV 860)



Audio

X 4/4 time guessed

- Why not 6/8?
  - $P(B_{3,E} \rightarrow SB_S\ SB_W\ SB_W \mid M_{2,3})$ is low

Conclusion

- PCFGs are a natural way to generate metrical trees.
- Lexicalization allows them to capture long range dependencies in order to detect patterns of strong and weak beats.
- Future Work
  - Live performance
    - Beat tracking
  - Incorporate melodic and harmonic information

Thank You

- Collaborator:
  - Mark Steedman
- Code: github.com/apmcleod/met-detection
- Questions?

Results By Meter

Meter Type	Inventions #	Inventions LPCFG	Fugues #	Fugues LPCFG
$\frac{6}{X}$	0	—	4	0.58
$\frac{3}{X}$	5	0.60	7	0.57
$\frac{2}{X}$	0	—	9	0.89
$\frac{4}{X}$	8	0.71	26	**0.90**
All	15	0.63	48	0.80