Alignment and Marginal Inference with SCFGs

April 12, 2014

Forced decoding

- Other names
  - Forced alignment
  - Alignment
  - Synchronous parsing
  - Three-way composition
- Why?
  - Compute expectations of

Wu, 1997

Items $[X, s, t, u, v]$

Axioms

$$\frac{}{[X, s, s+1, u, u+1]} \quad X \rightarrow \langle f_s, e_u \rangle \in G$$

$$\frac{}{[X, s, s+1, u, u]} \quad X \rightarrow \langle f_s, \varepsilon \rangle \in G$$

$$\frac{}{[X, s, s, u, u+1]} \quad X \rightarrow \langle \varepsilon, e_u \rangle \in G$$

Wu, 1997

Rules

$$\frac{[X, s, j, u, k] \ [Y, j, t, k, v]}{[Z, s, t, u, v]} \quad Z \rightarrow \langle X \ Y, \boxed{1} \ \boxed{2} \rangle \in G$$

$$\frac{[X, s, j, k, v] \ [Y, j, t, u, k]}{[Z, s, t, u, v]} \quad Z \rightarrow \langle X \ Y, \boxed{2} \ \boxed{1} \rangle \in G$$

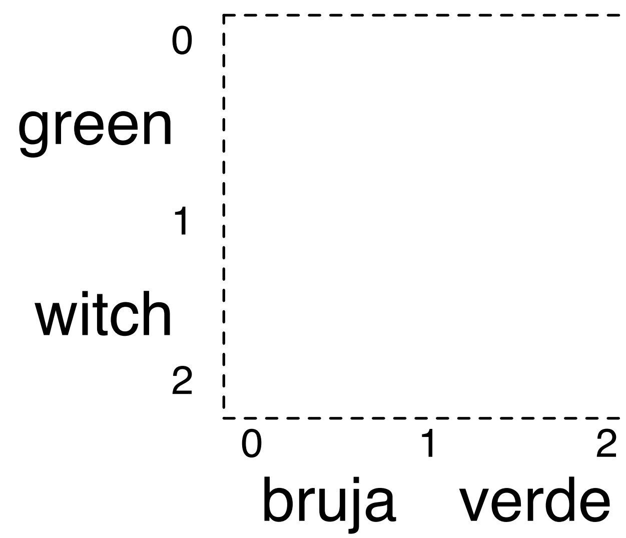
Goal $[S, 1, 1, m+1, n+1]$

Grammar

$$\mathrm{NP} \rightarrow \langle \mathrm{NN}\ \mathrm{JJ}, \boxed{2}\ \boxed{1} \rangle$$

$$\mathrm{NN} \rightarrow \langle bruja, witch \rangle$$

$$\mathrm{JJ} \rightarrow \langle verde, green \rangle$$



Items

Grammar

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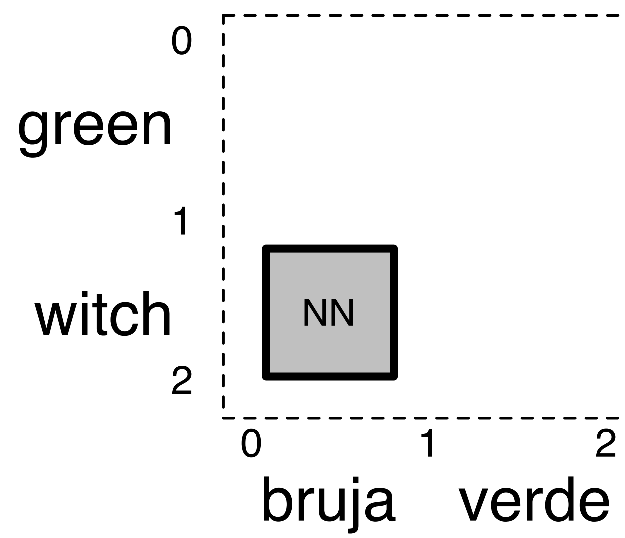

Items

$$[\mathrm{NN}, 0, 1, 1, 2]$$

Grammar

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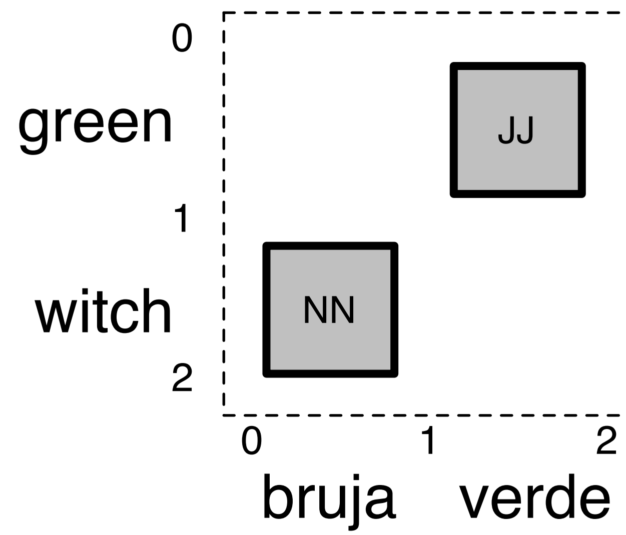

Items

$$[\mathrm{NN}, 0, 1, 1, 2]$$

$$[\mathrm{JJ}, 1, 2, 0, 1]$$

Grammar

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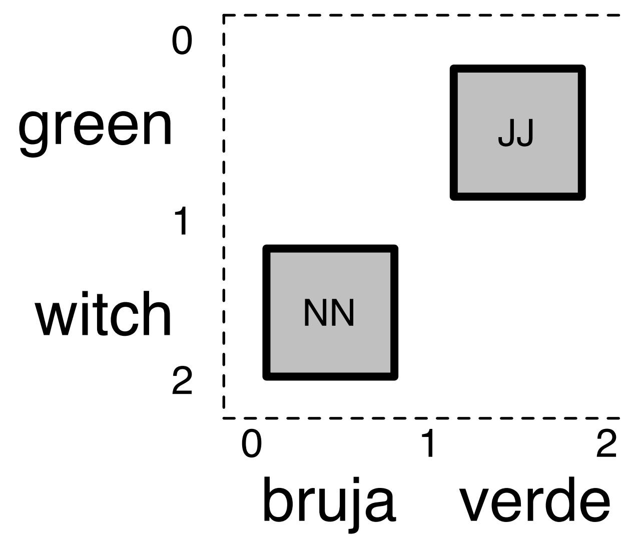

Items

$$[\mathrm{NN}, 0, 1, 1, 2]$$

$$[\mathrm{JJ}, 1, 2, 0, 1]$$

$$\frac{[X, s, j, k, v]\ \ [Y, j, t, u, k]}{[Z, s, t, u, v]} \quad Z \rightarrow \langle X\ Y, \boxed{2}\ \boxed{1} \rangle \in G$$

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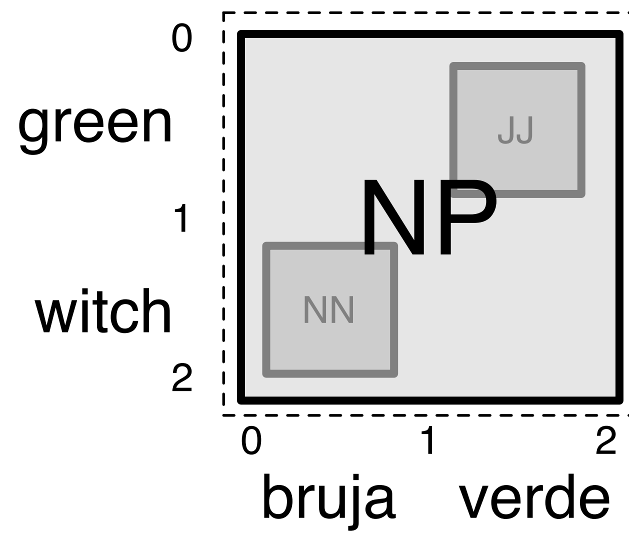

Items

$$[\mathrm{NN}, 0, 1, 1, 2]$$

$$[\mathrm{JJ}, 1, 2, 0, 1]$$

$$[\mathrm{NP}, 0, 2, 0, 2]$$

Wu, 1997 - Analysis

Rules

$$\frac{[X, s, j, u, k] \; [Y, j, t, k, v]}{[Z, s, t, u, v]} \quad Z \rightarrow \langle X \; Y, \boxed{1} \; \boxed{2} \rangle \in G$$

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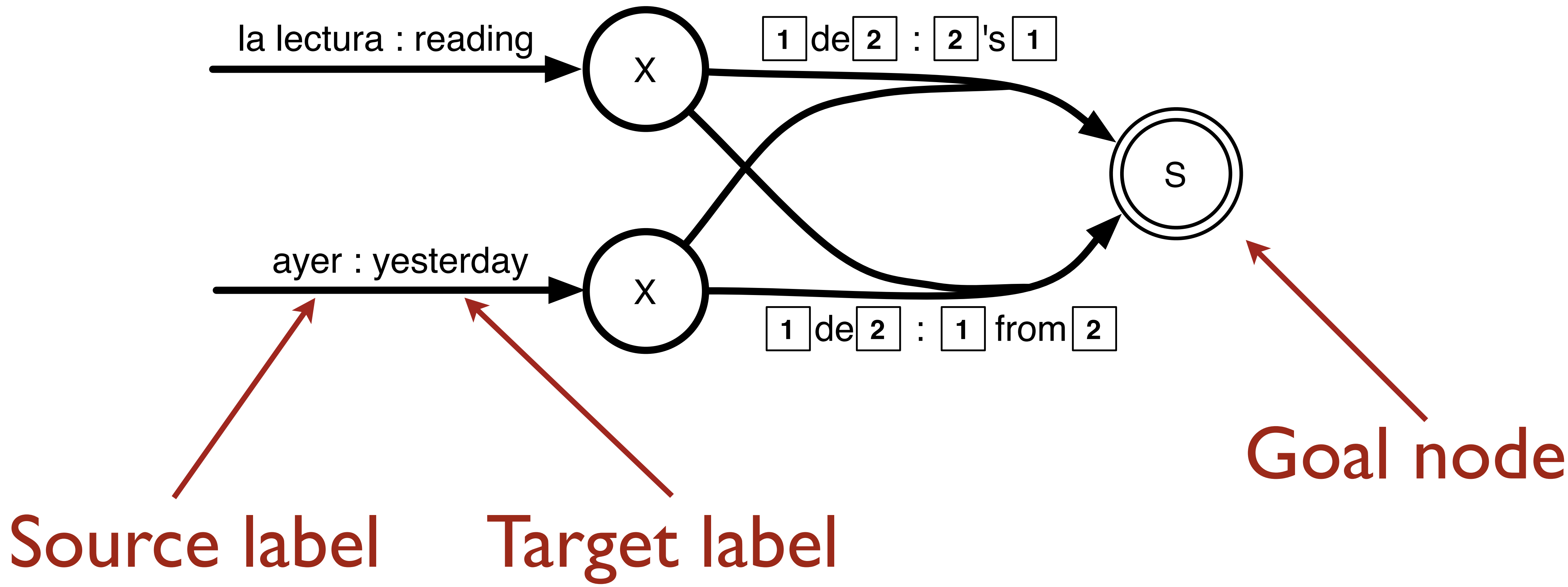
1 2 3 4 5 6

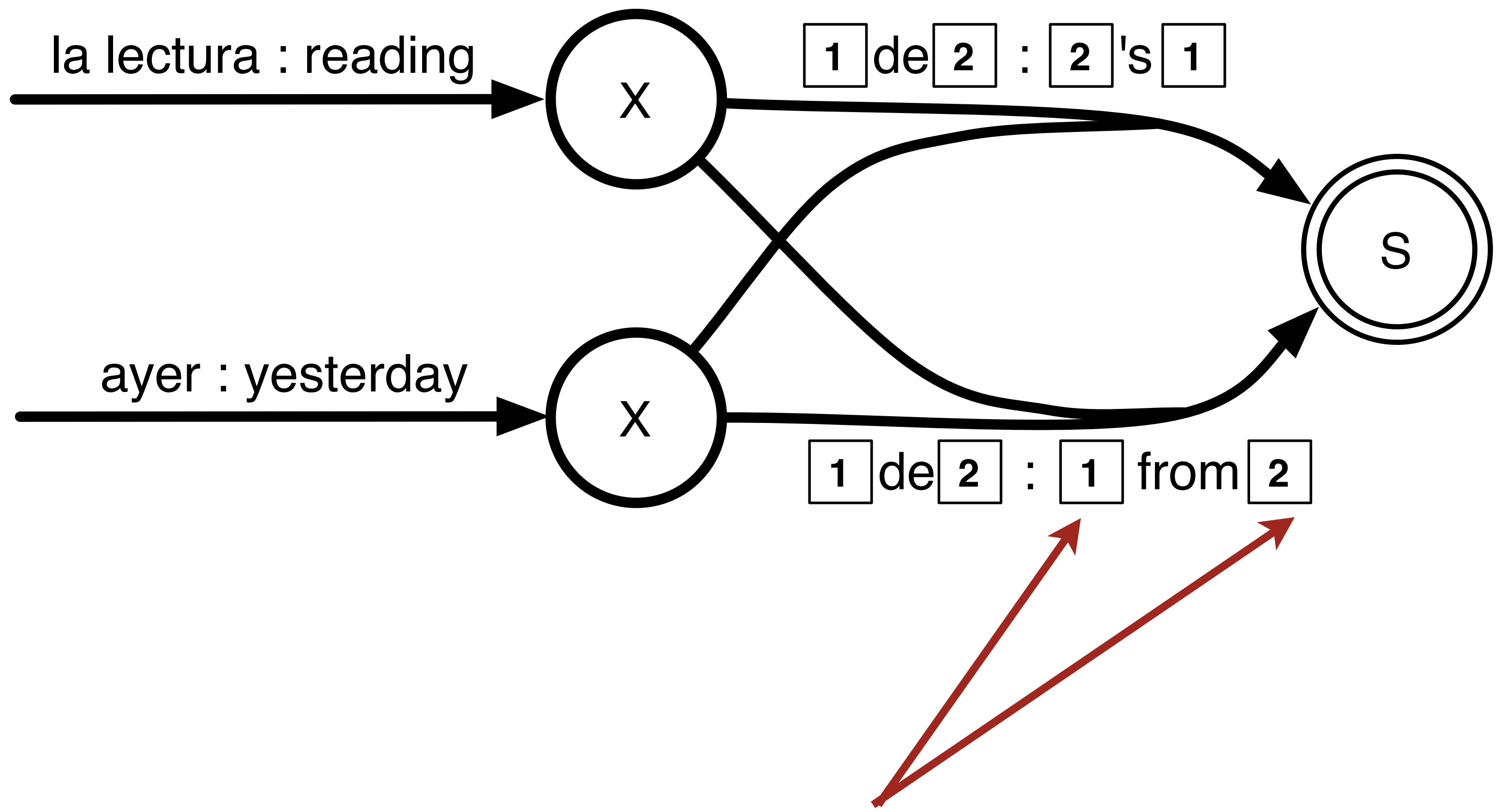
Run-time: $\mathcal{O}(n^6)$

Can we do better?

Hypergraph review



Hypergraph review



Substitution sites / variables / non-terminals

Hypergraphs as Grammars

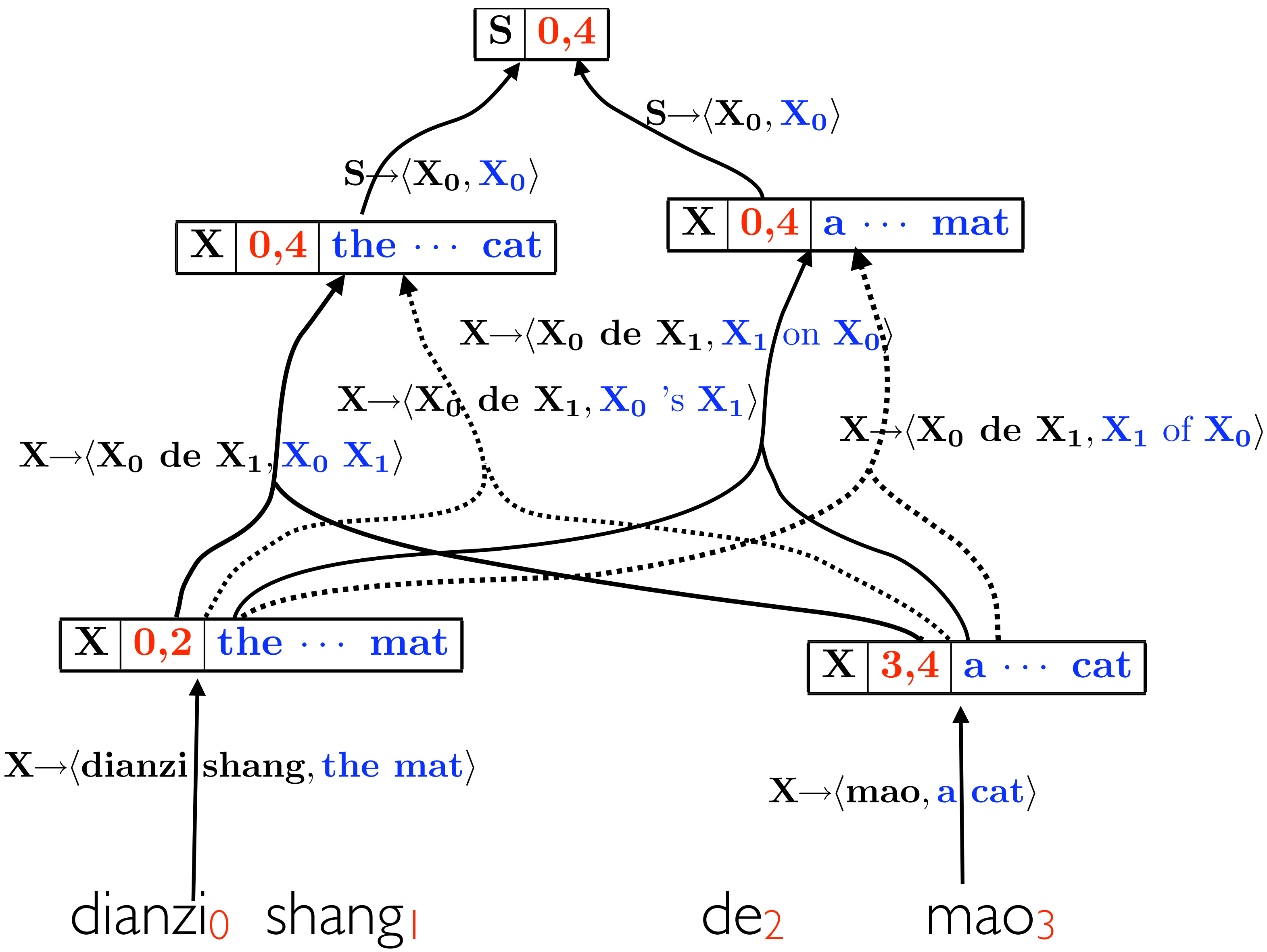
- **Claim:** A hypergraph is isomorphic to a (synchronous) CFG
- LM integration can be understood as the **intersection** of an regular and CF language
- Cube pruning approximates this intersection

Two-Parse Algorithm (Dyer, 2010)

Input: <*dianzi shiang de mao* , *a cat on the mat*>

With thanks and apologies to Zhifei Li.

Input: <*dianzi shiang de mao* , *a cat on the mat*>



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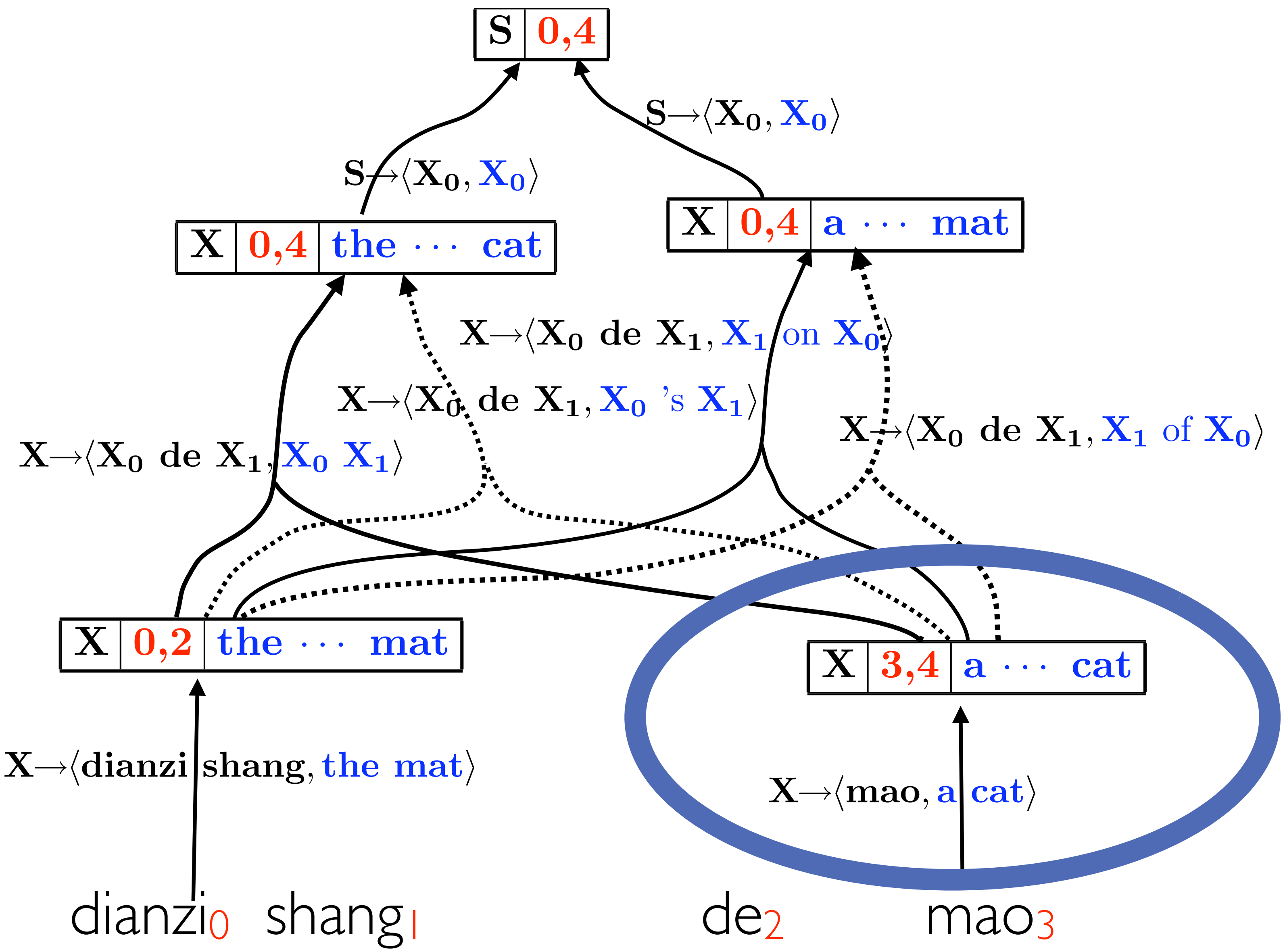
Input: <*dianzi shiang de mao* , *a cat on the mat*>

Isomorphic CFG

[X34] → *a cat*



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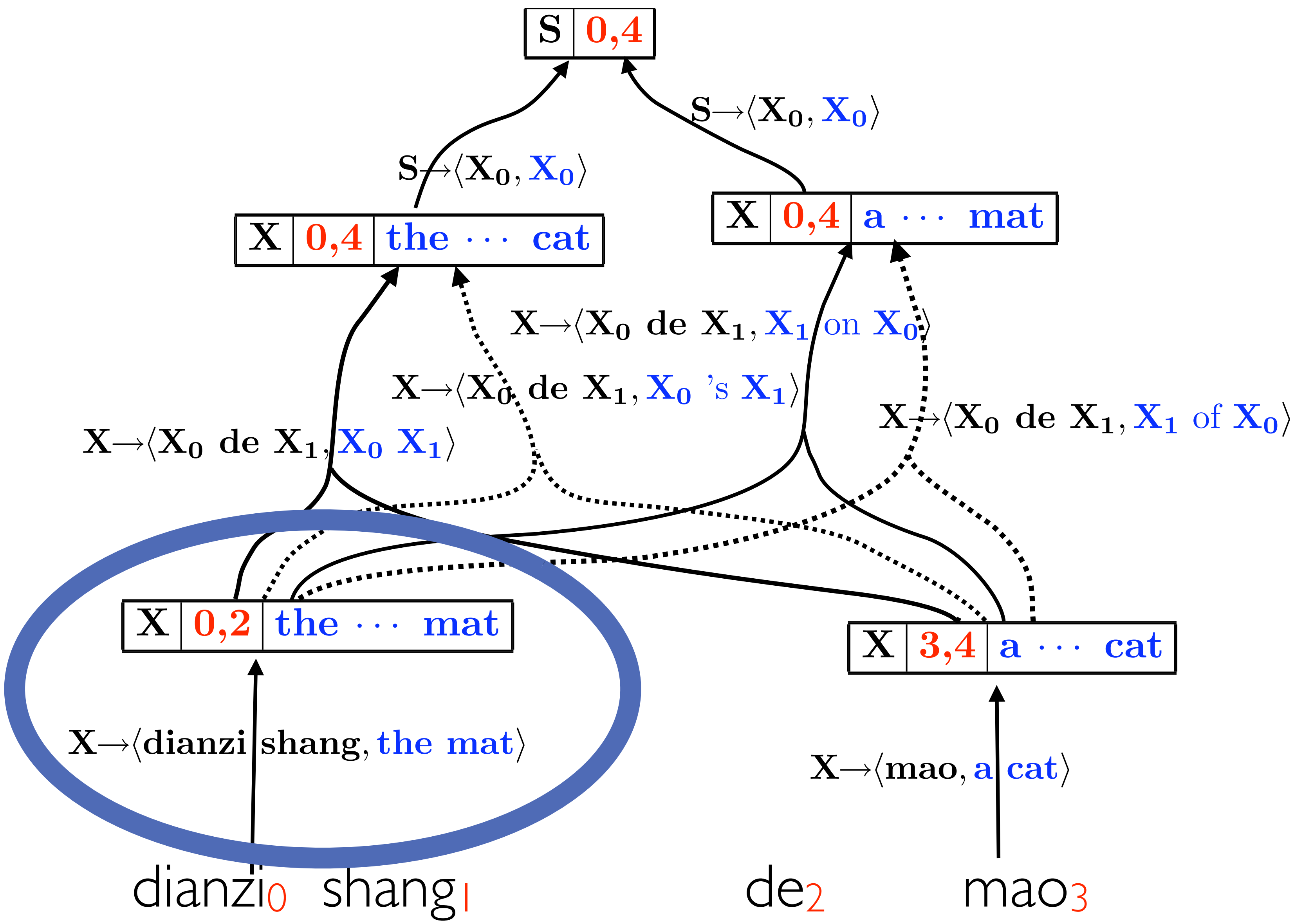
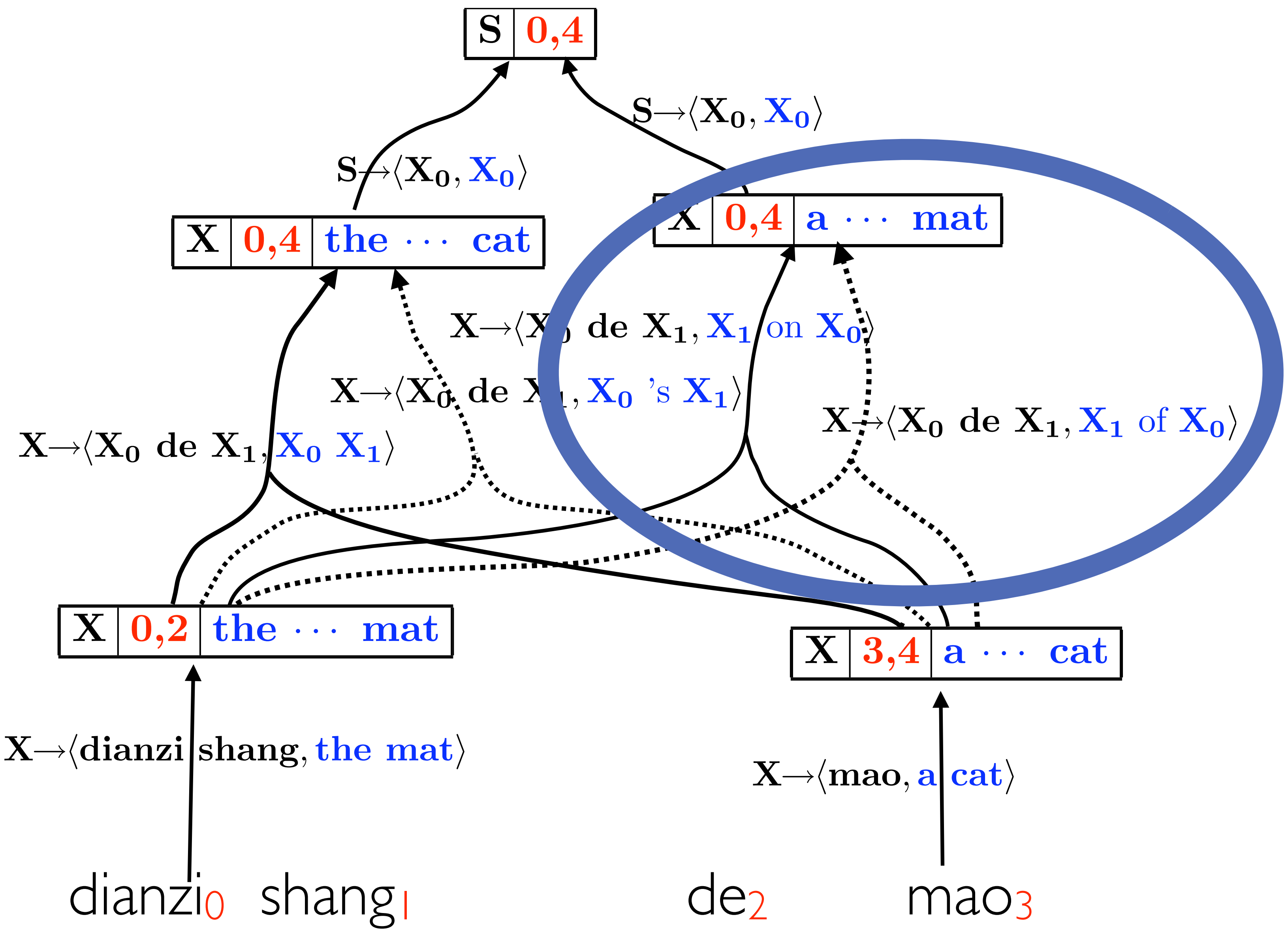


Isomorphic CFG

[X34] → *a cat*

[X02] → *the mat*

Input: <*dianzi shiang de mao* , *a cat on the mat*>



Isomorphic CFG

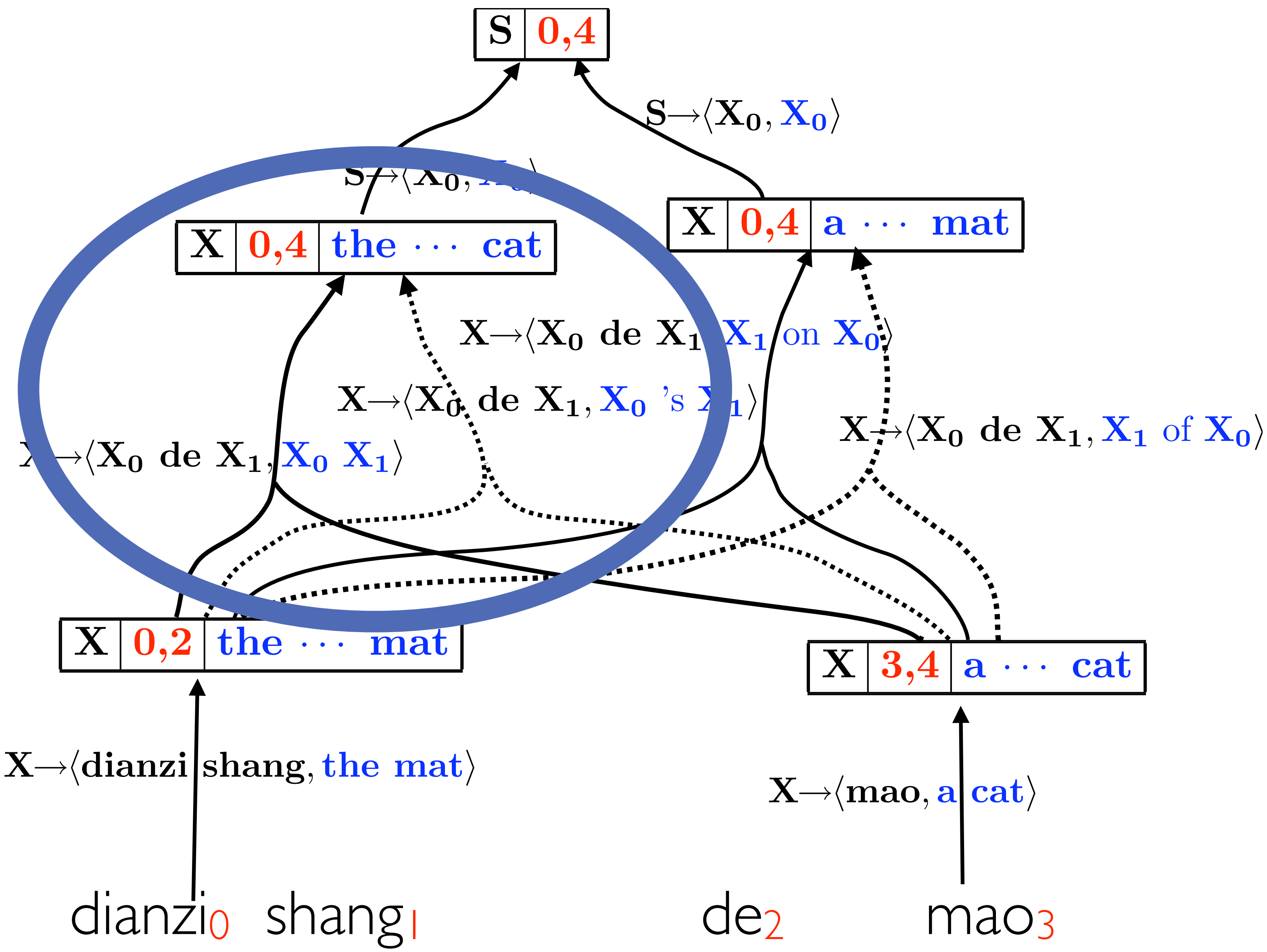
[X34] → *a cat*

[X02] → *the mat*

[X04a] → [X34] *on* [X02]

[X04a] → [X34] *of* [X02]

Input: <*dianzi shiang de mao* , *a cat on the mat*>



Isomorphic CFG

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[X04a] → [X34] *on* [X02]

[X04a] → [X34] *of* [X02]

[X04b] → [X02] *'s* [X34]

[X04b] → [X02] [X34]

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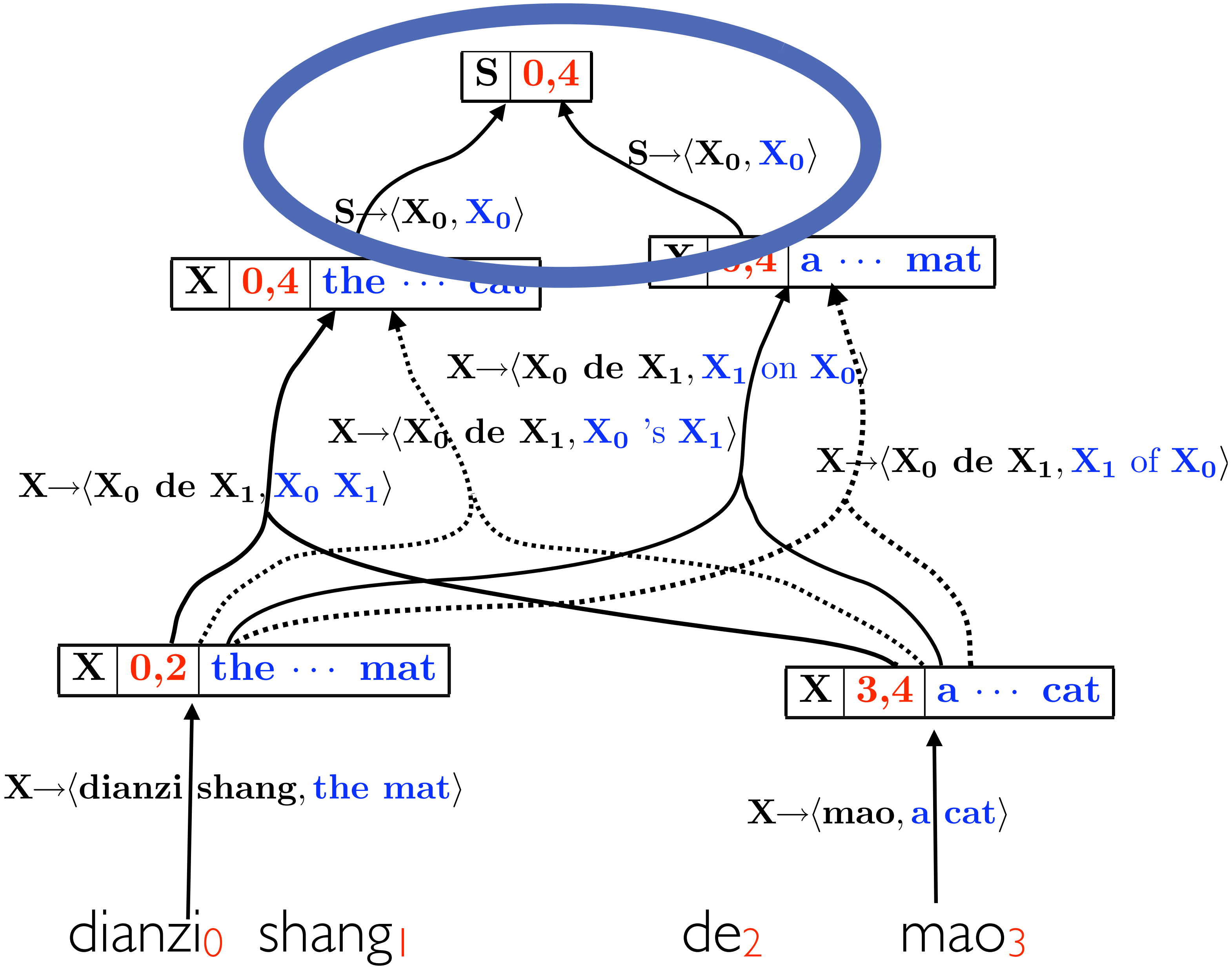

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[X04b] → [X02] [X34]

[S] → [X04a]

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a cat *on* *the mat*

Input: <*dianzi shiang de mao* , *a cat on the mat*>

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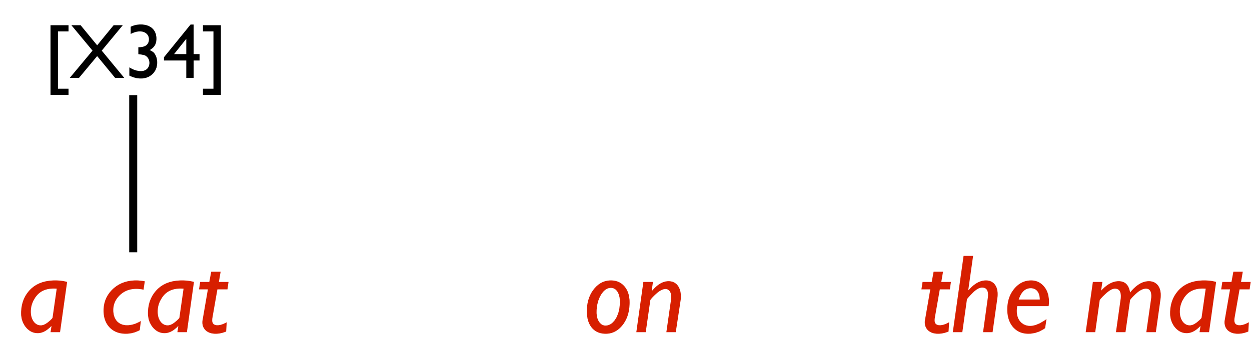

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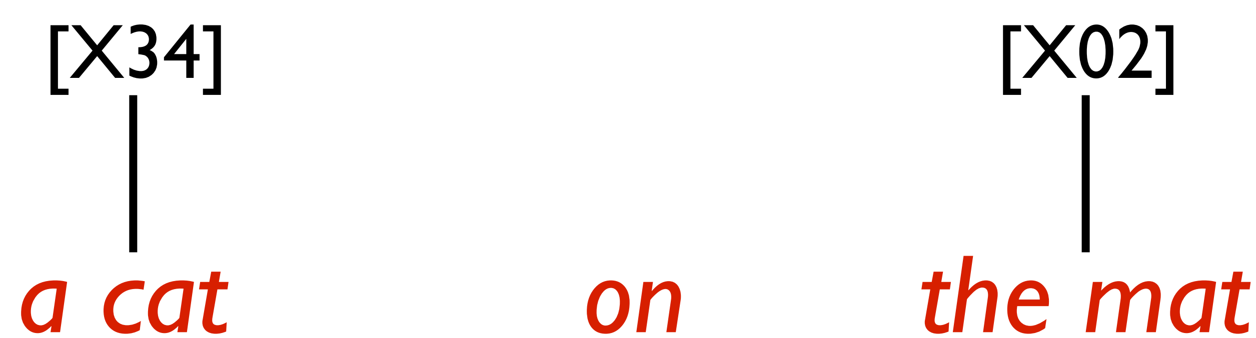

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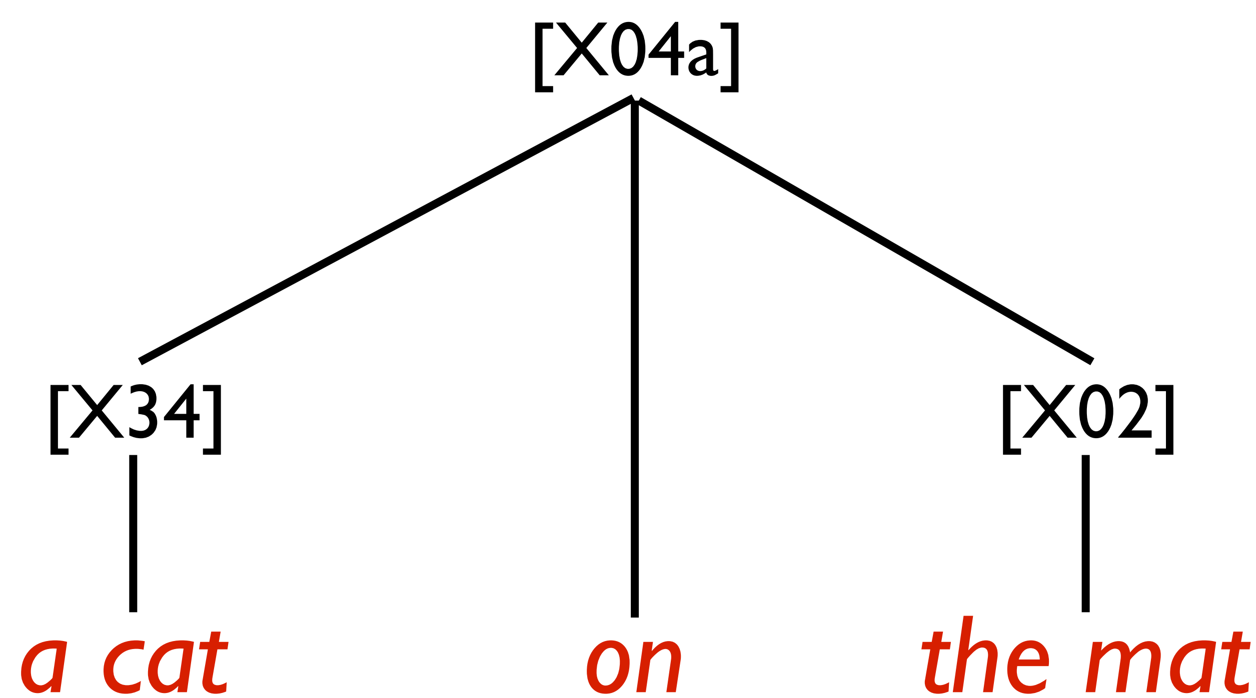

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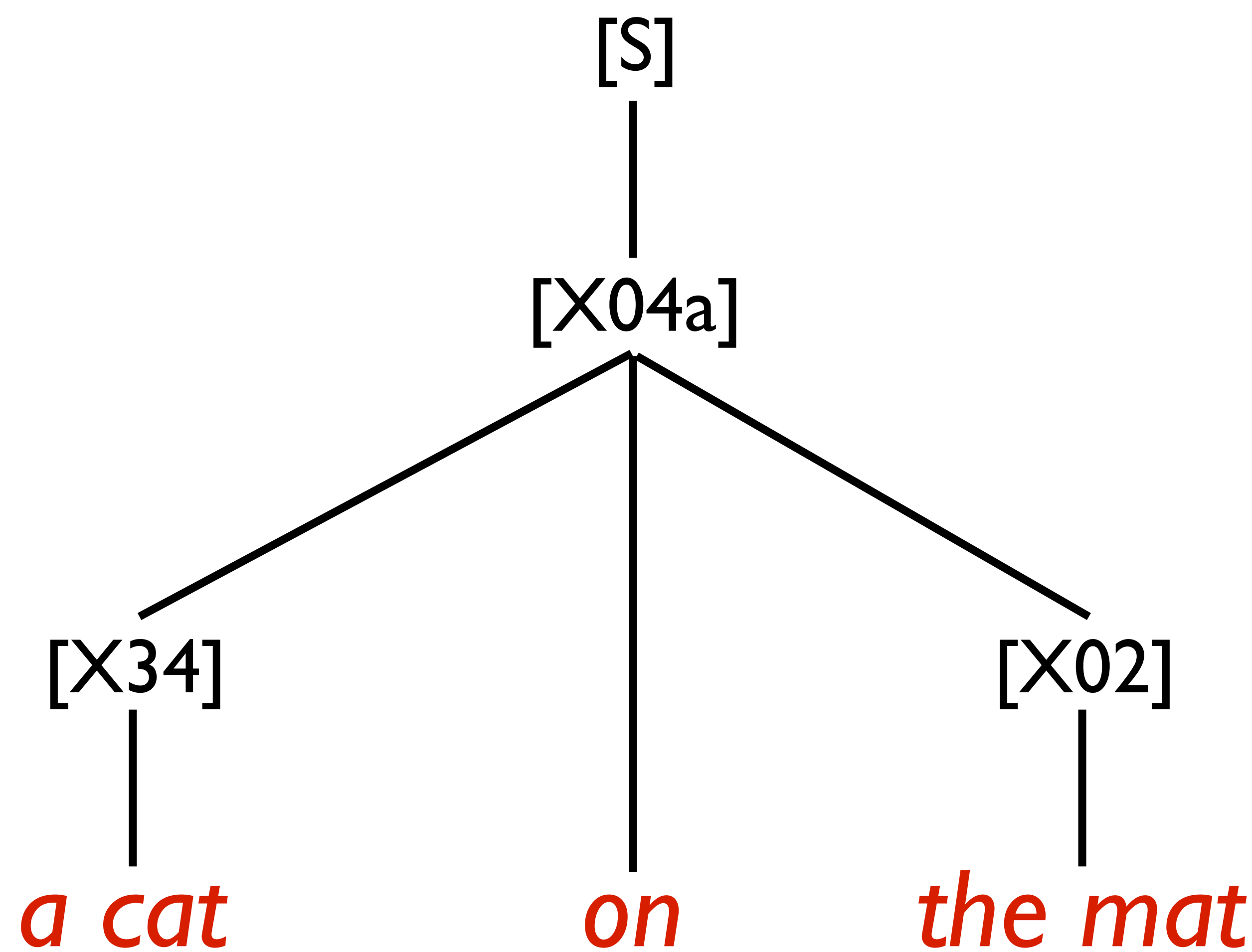
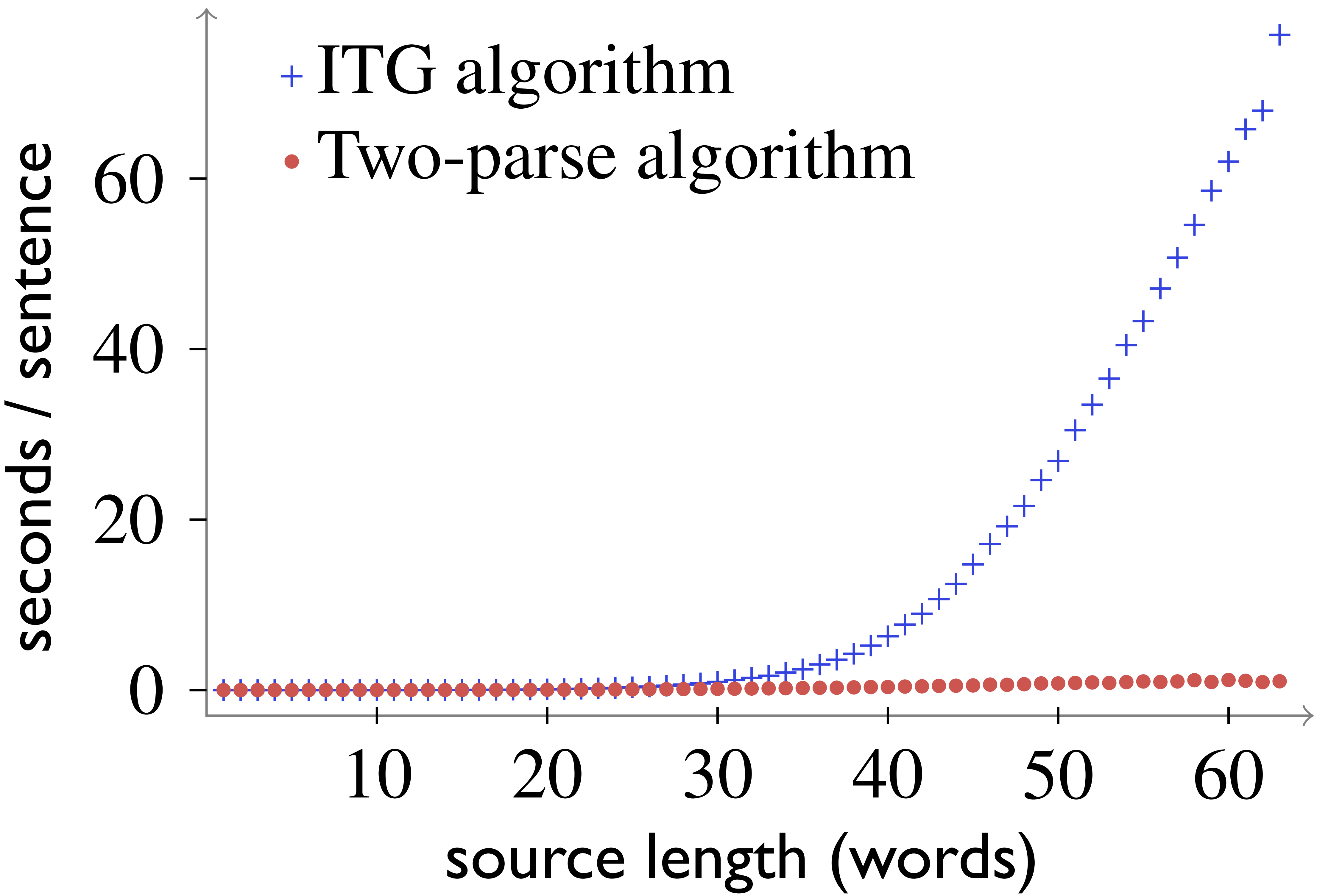


Two Algorithms

- **ITG algorithm** (Wu, 1997)
  - Jointly parse both source and target
  - Only works for binary ITGs (although generalizable)
  - Runs in $\Theta(n^6)$
- **Two-parse algorithm** (Dyer, 2010)
  - Parse source, then parse target
  - Works with any SCFG
  - For binary ITGs runs in $O(n^6)$


ITG algorithm
Two-parse algorithm
seconds / sentence
0
20
40
60
10
20
30
40
50
60
source length (words)