Hierarchical Search for Parsing

Adam Pauls and Dan Klein

Motivation

- Modern parsers users very large grammars (millions of rules!)

- Coarse-to-Fine has proven successful (Charniak and Caraballo 1998)

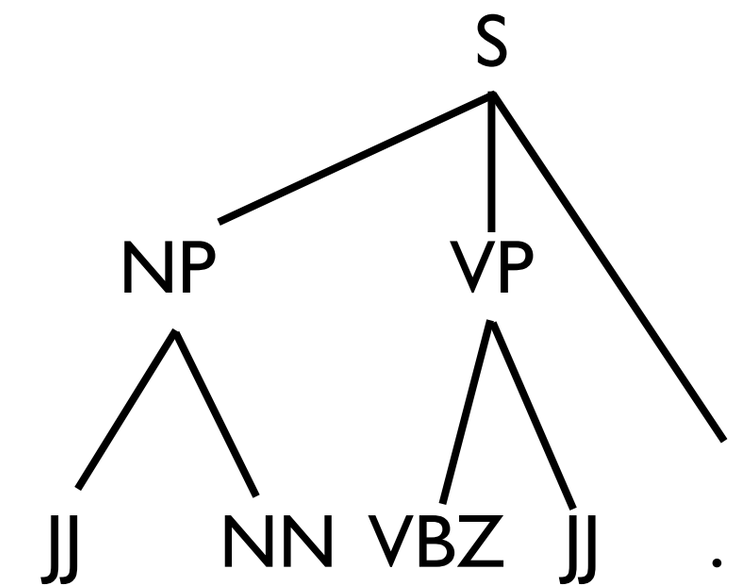
- Multi-level or Hierarchical Coarse-to-Fine works even better (Charniak and Johnson 2005, Petrov and Klein 2007)

- In this talk, we explore an optimal hierarchical search method: *Hierarchical A**

Hierarchical Setting

fast parsing is fun .

Hierarchical Setting



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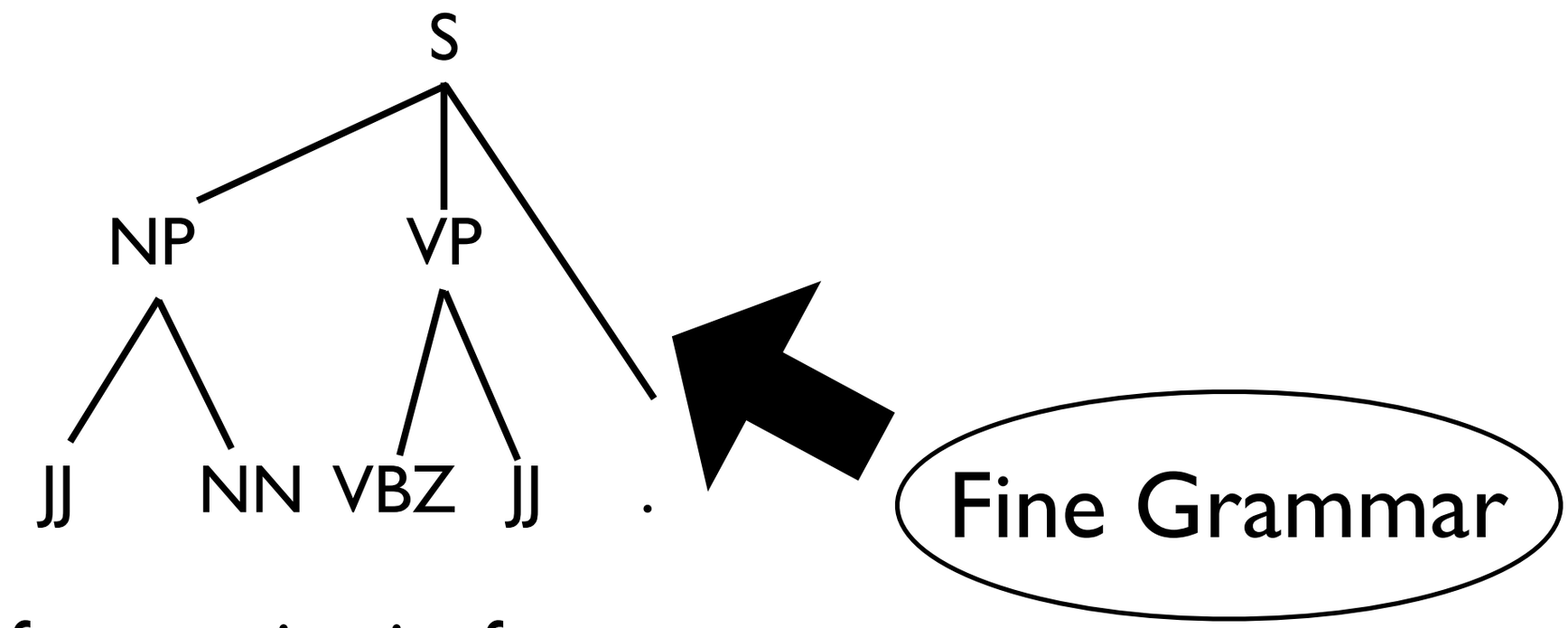

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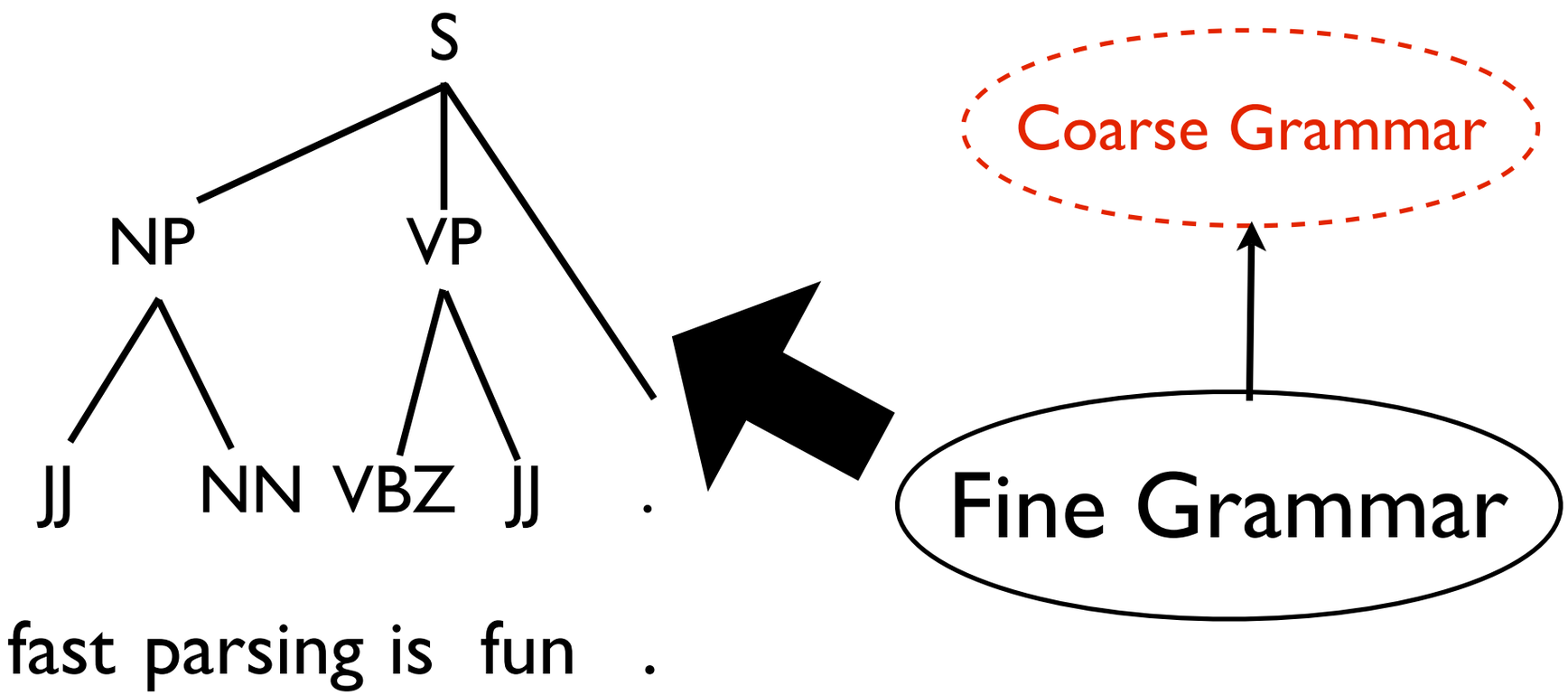

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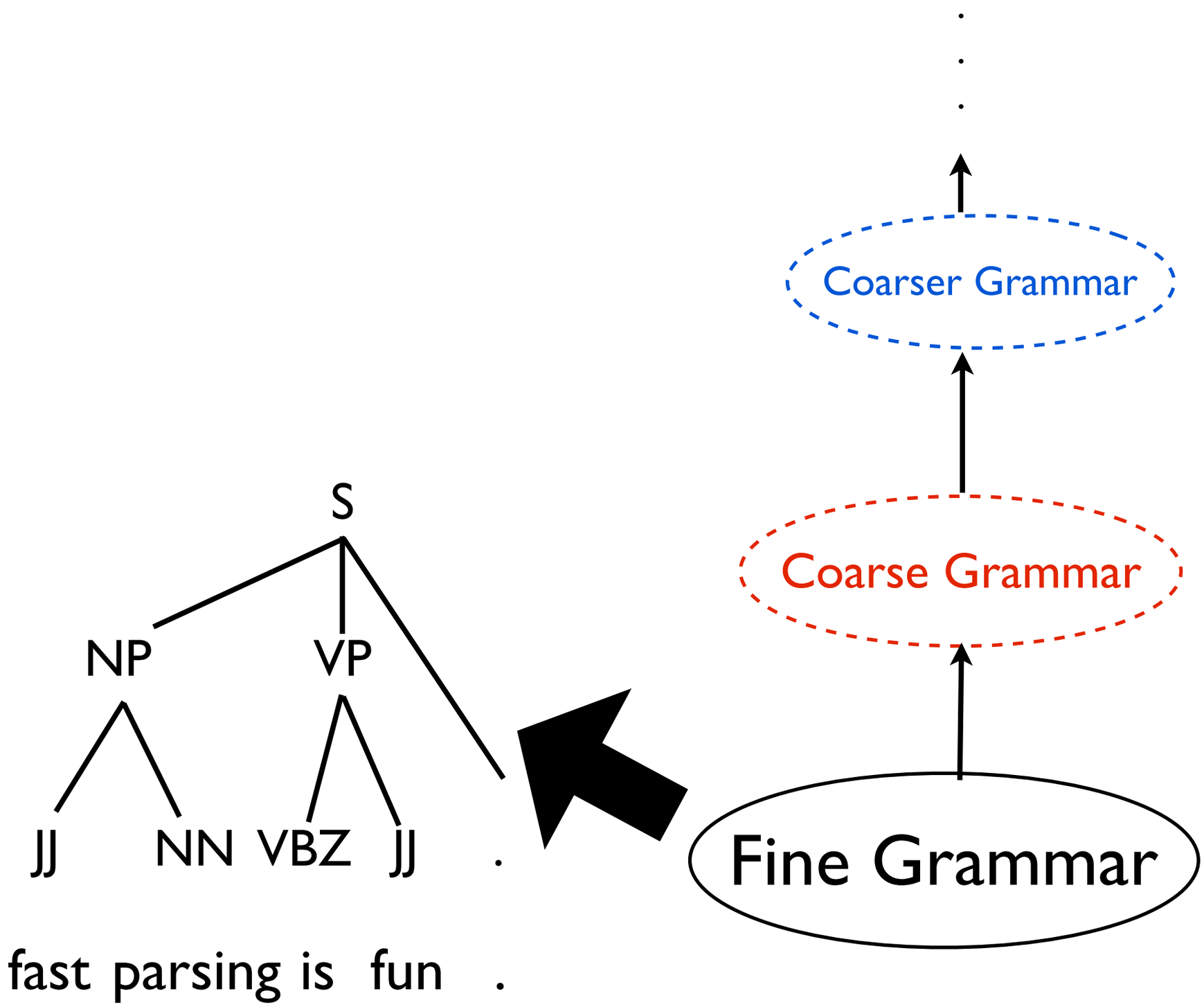

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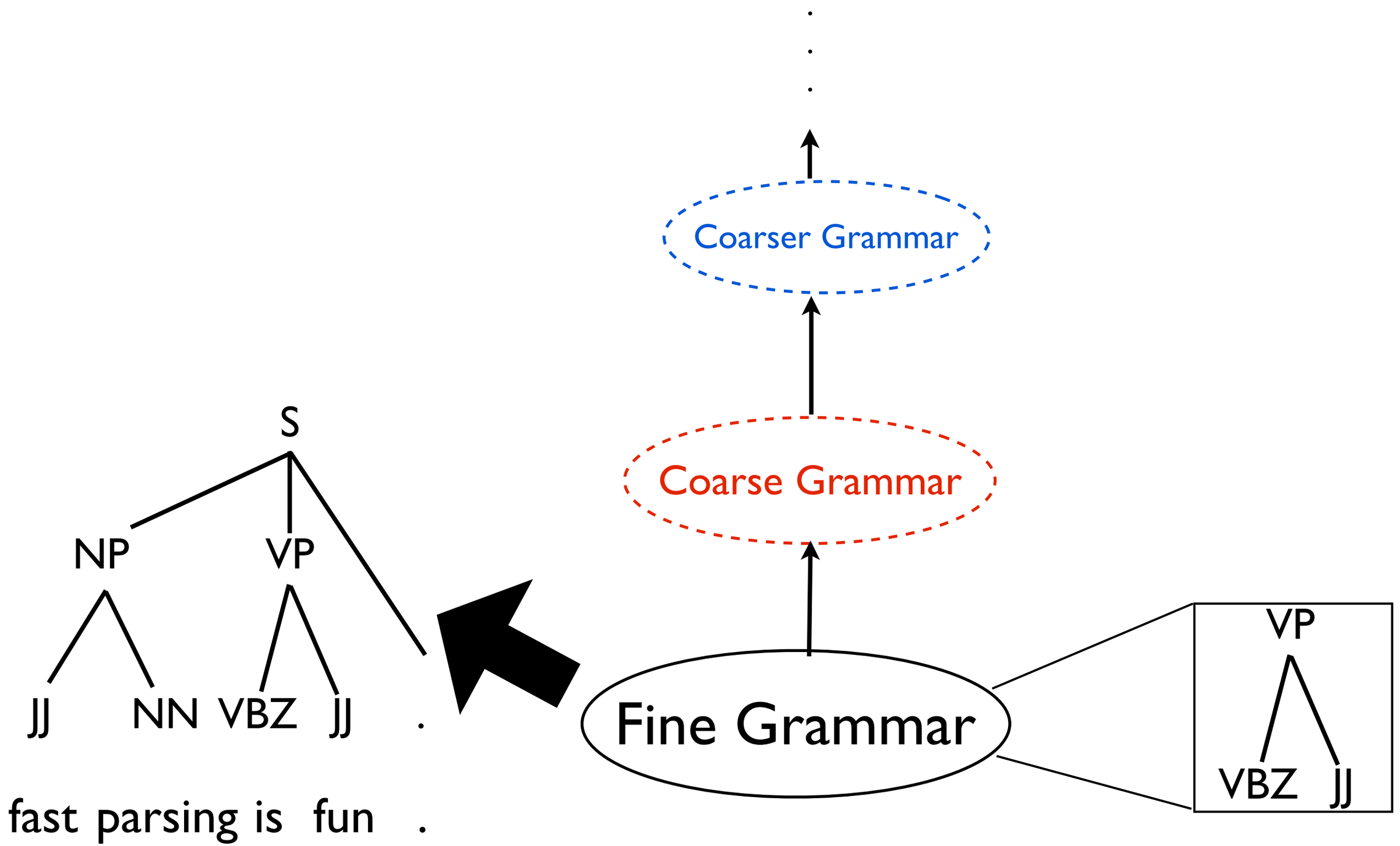

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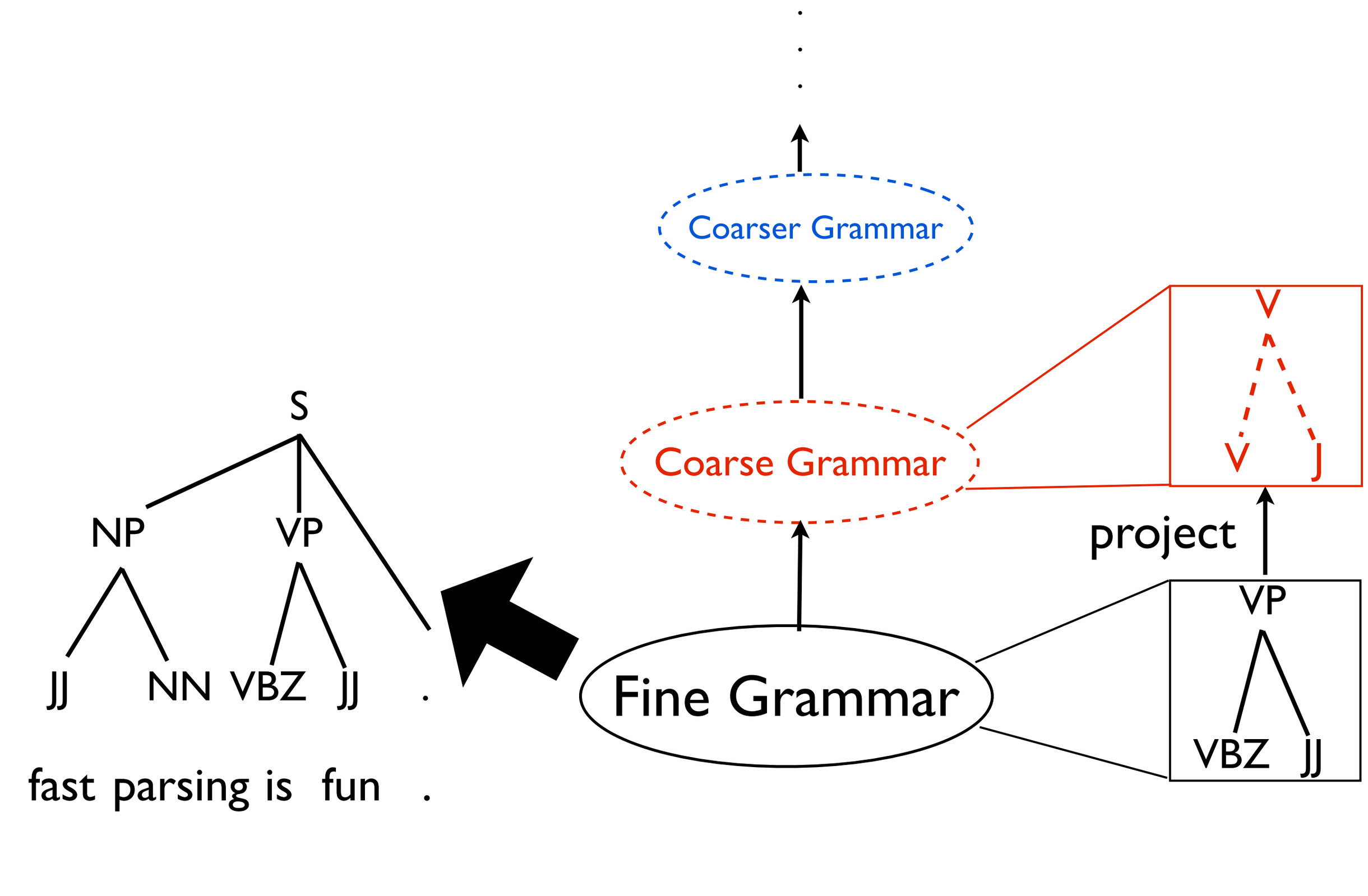
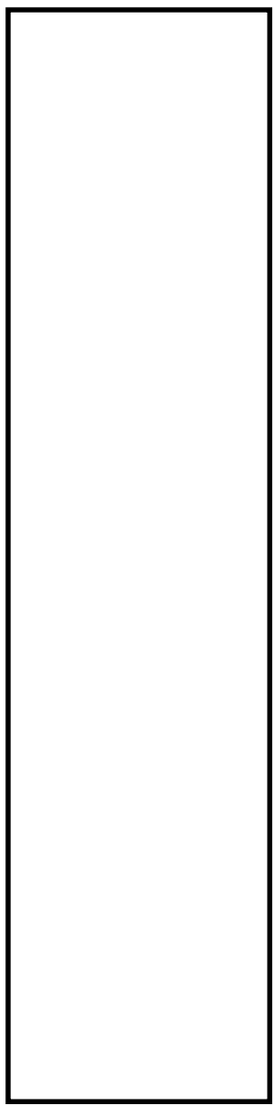


Agenda-Based Search



Agenda

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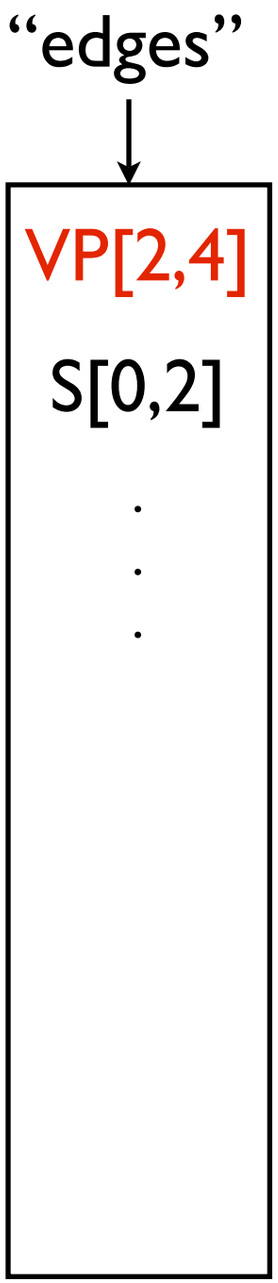

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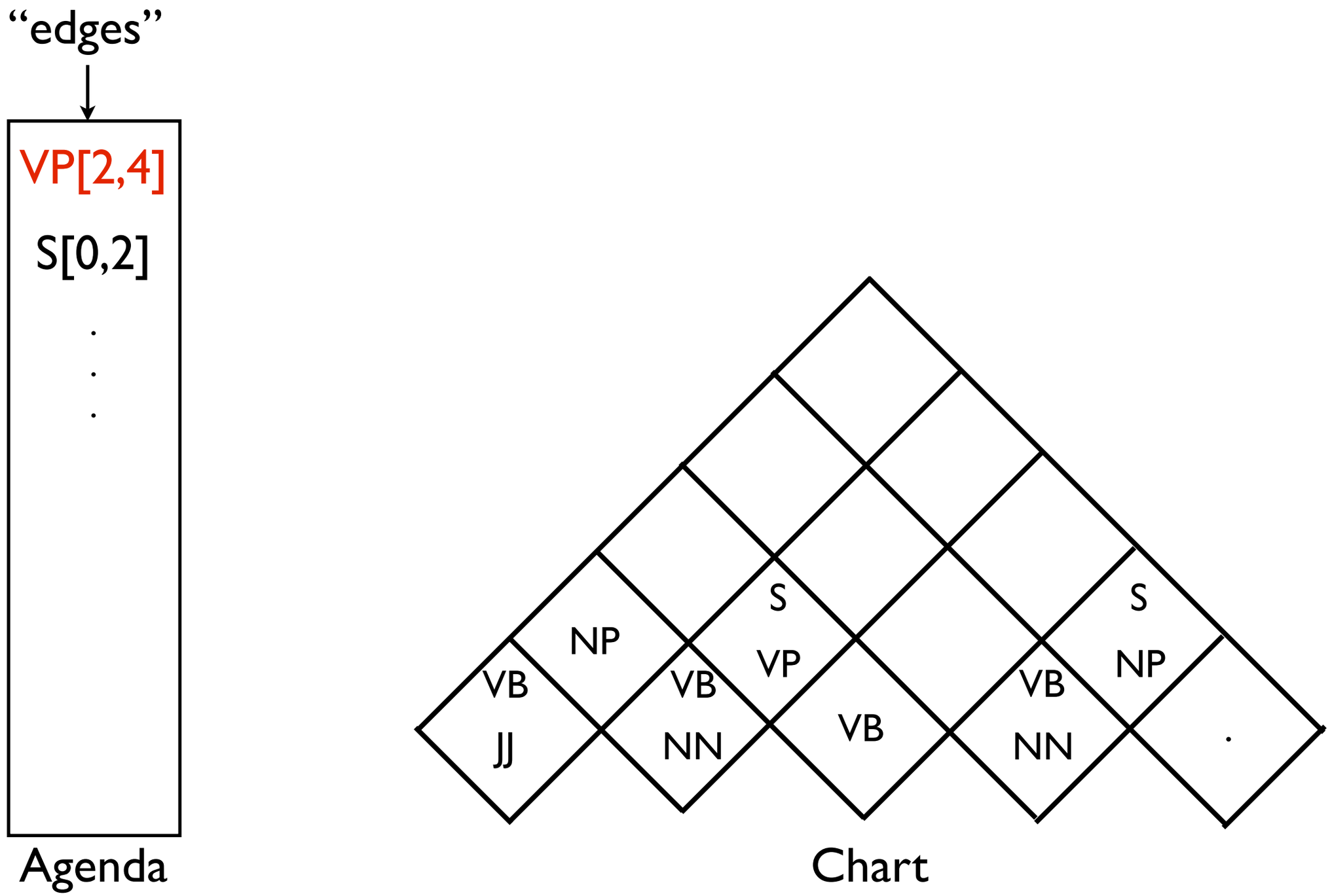

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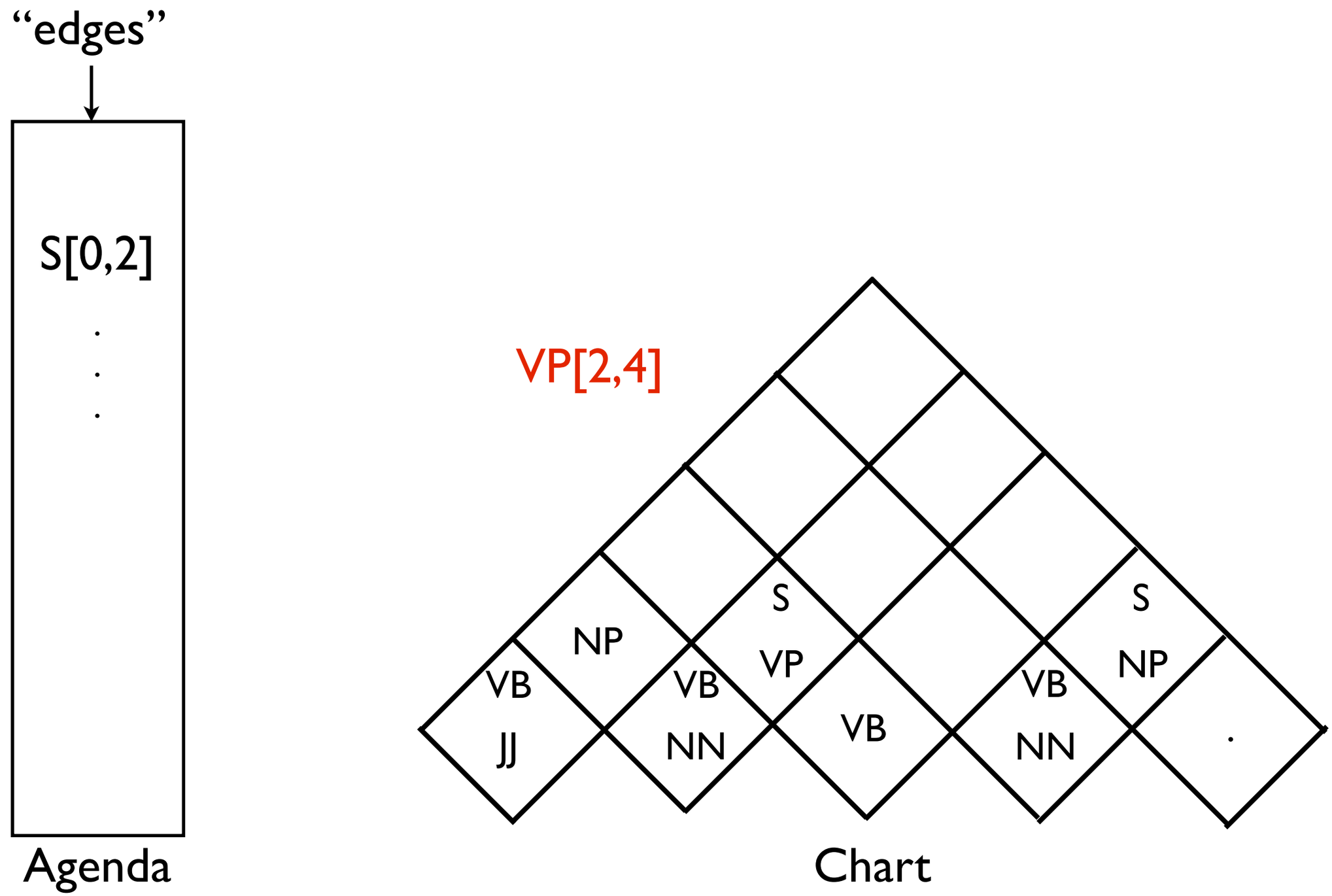

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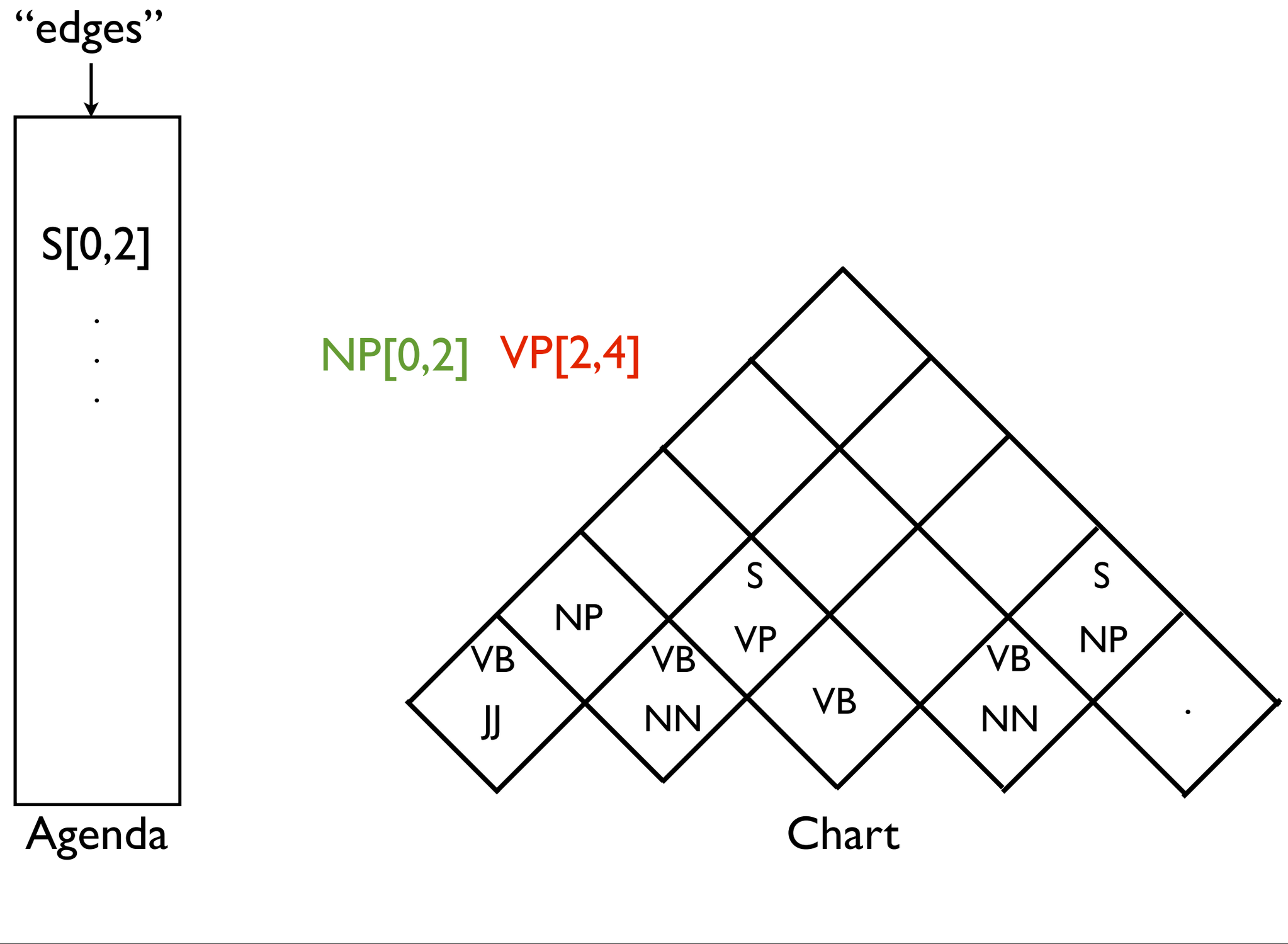

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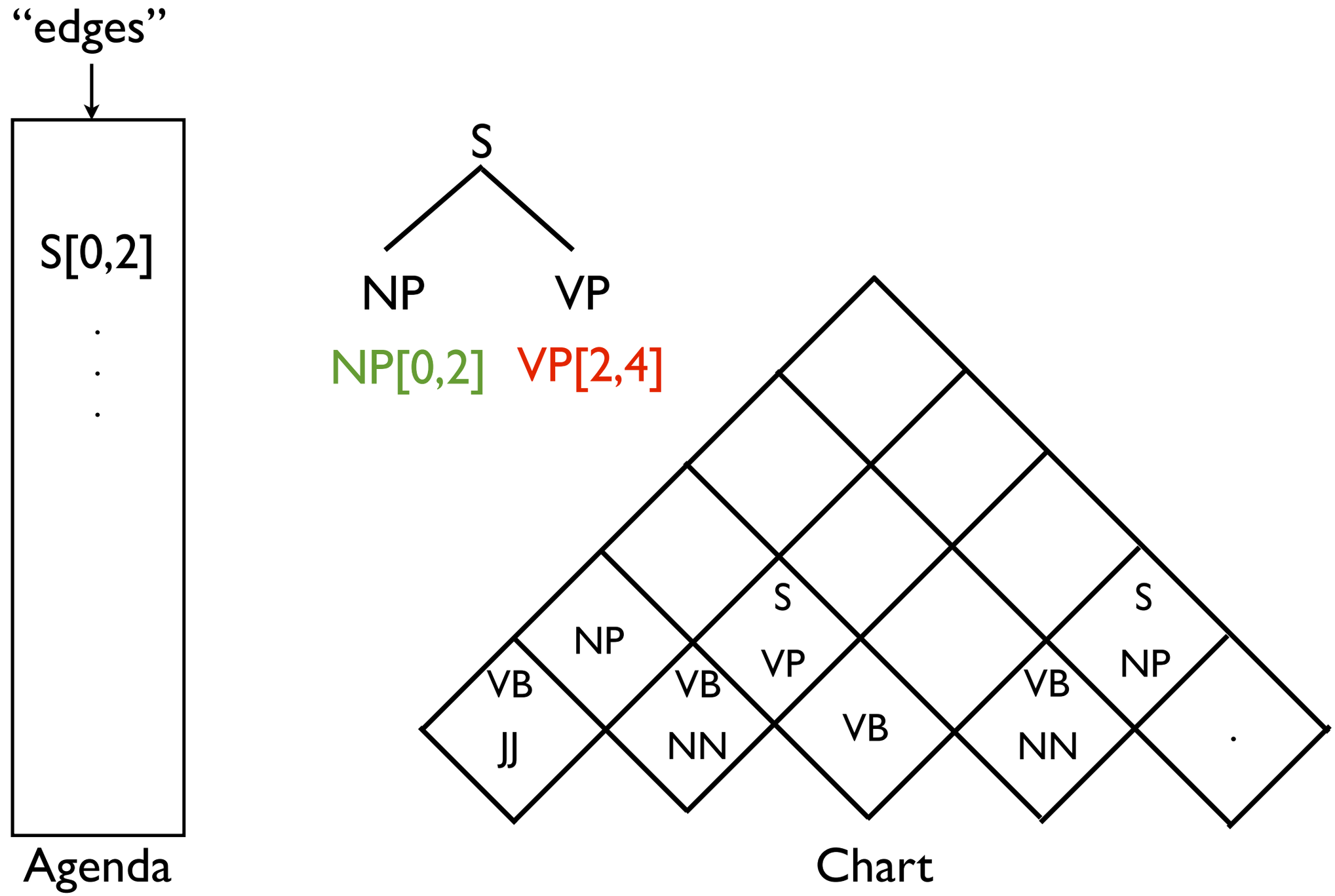

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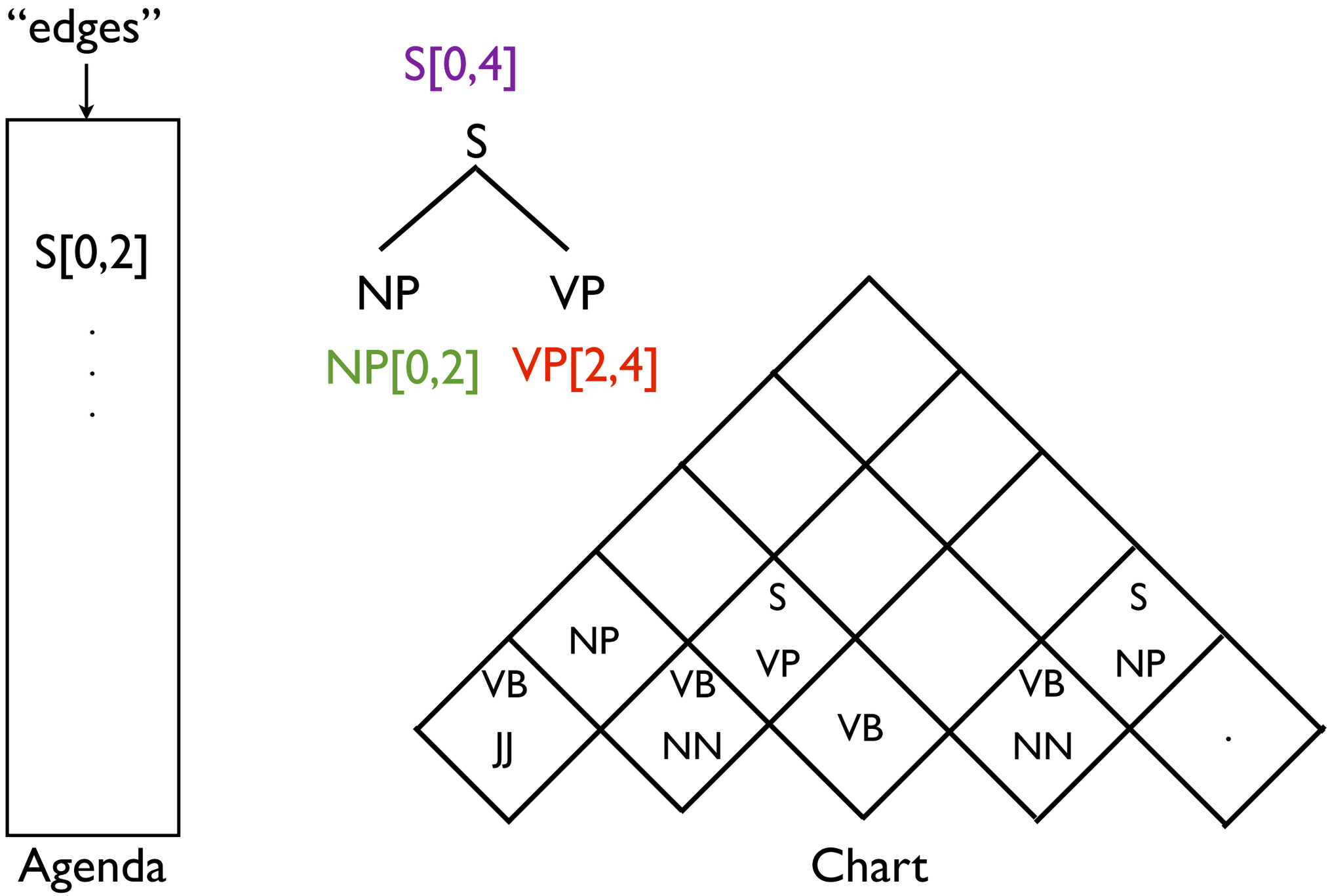

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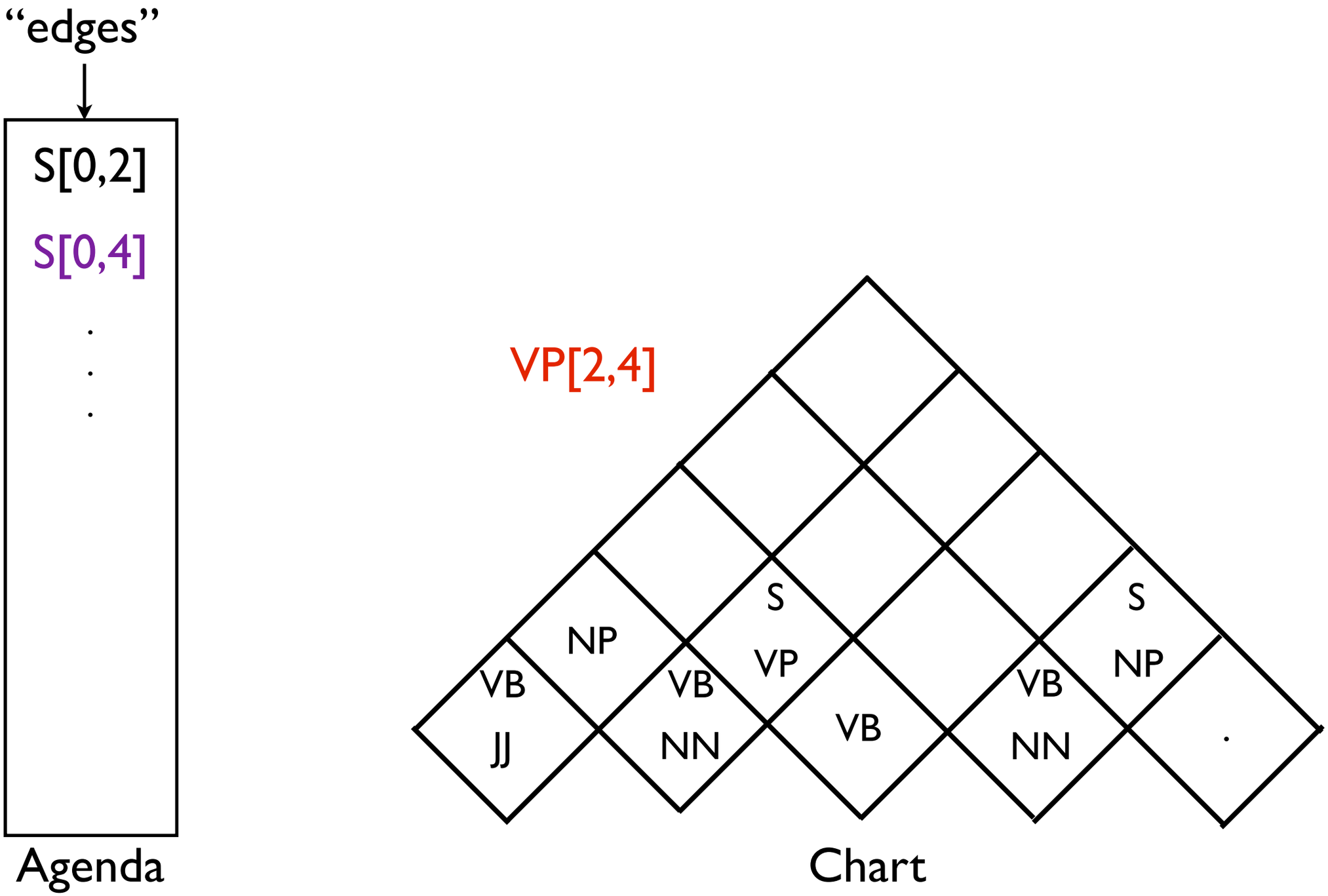

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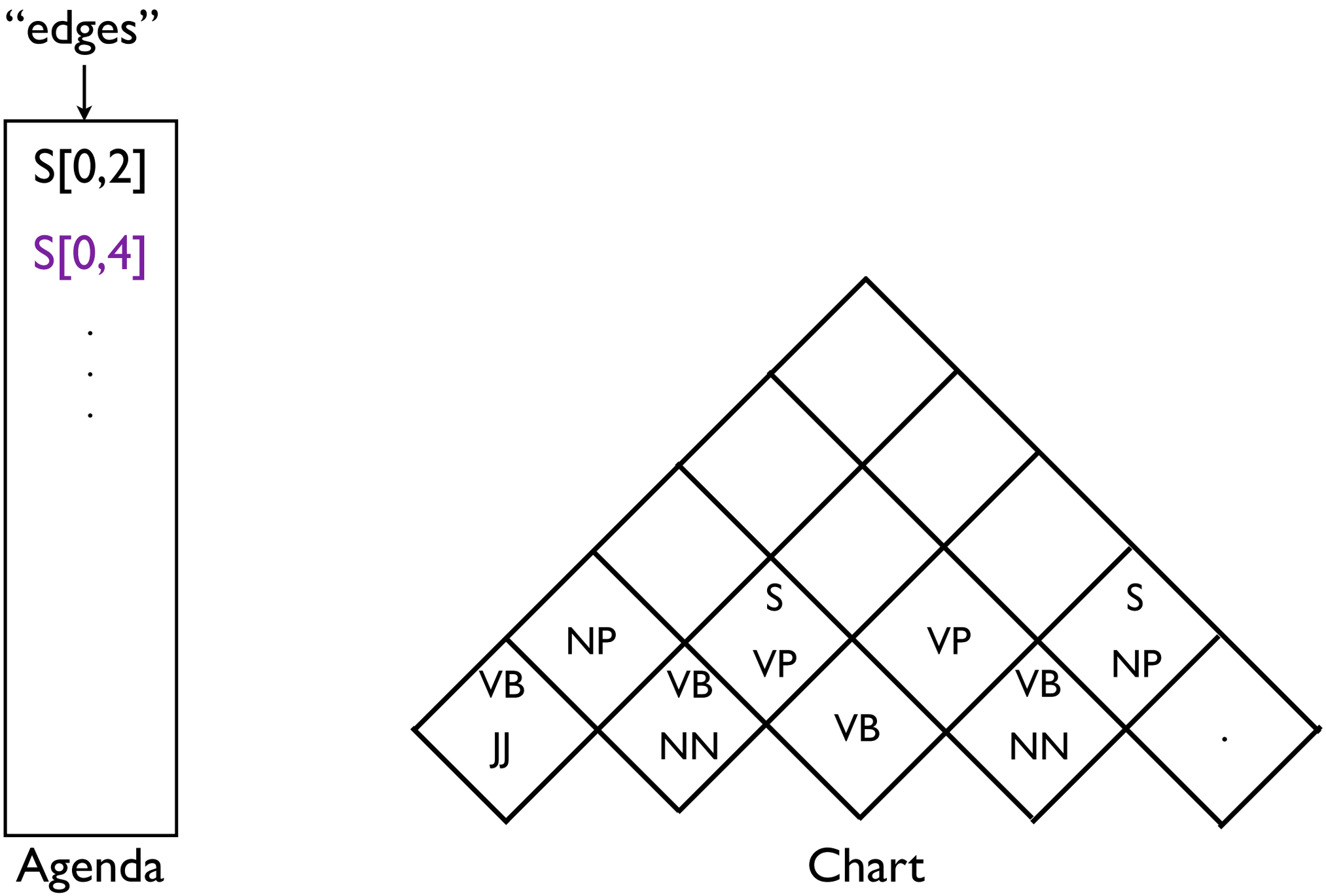

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Building Edges

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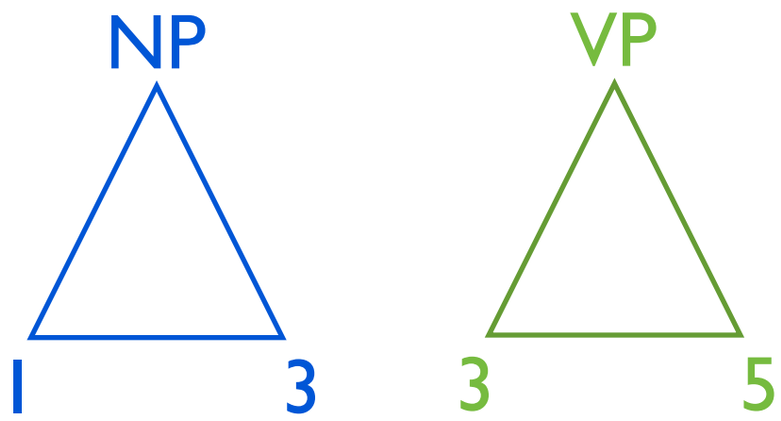

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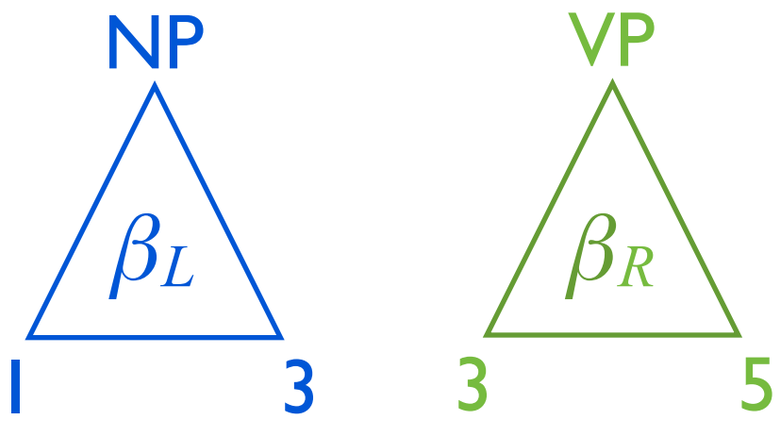

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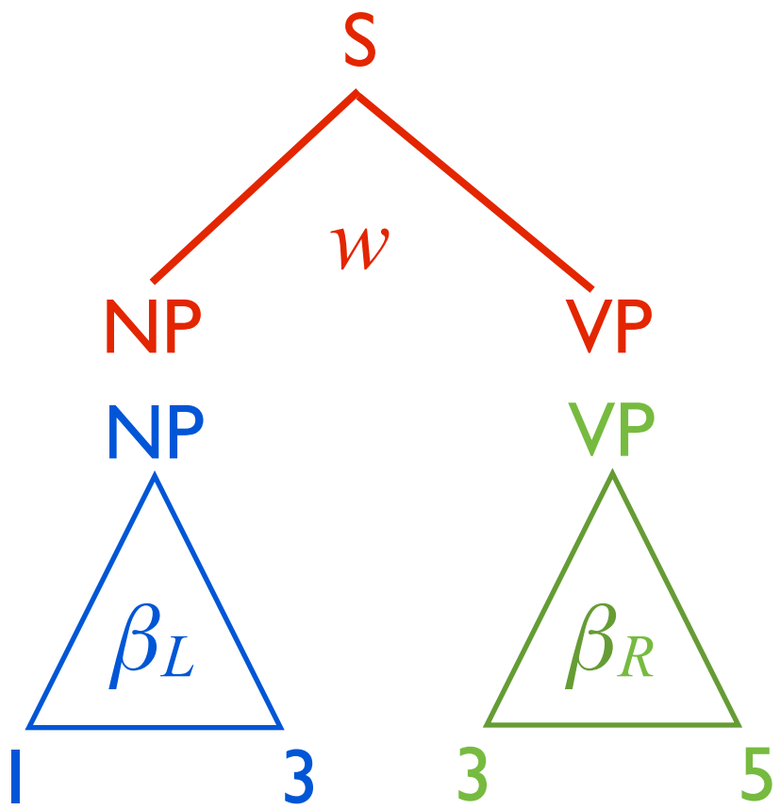

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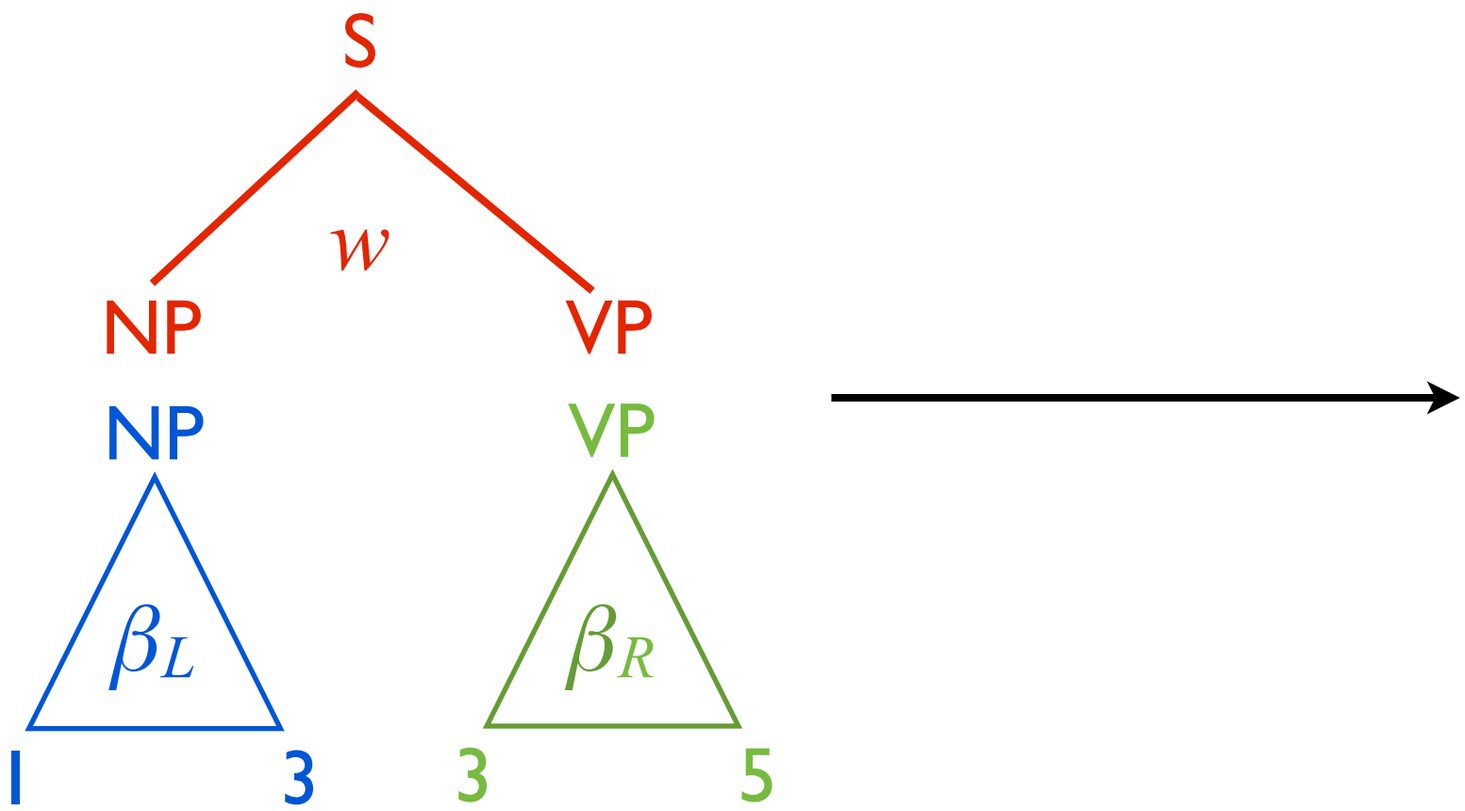

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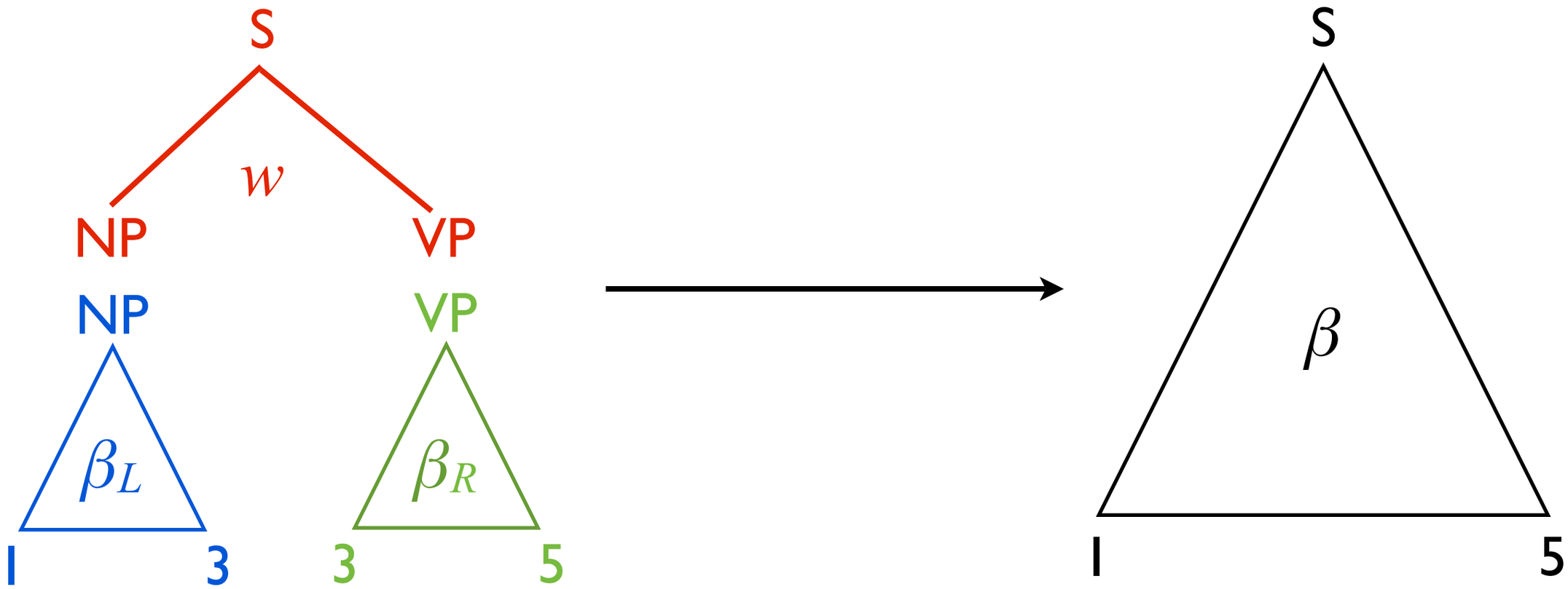

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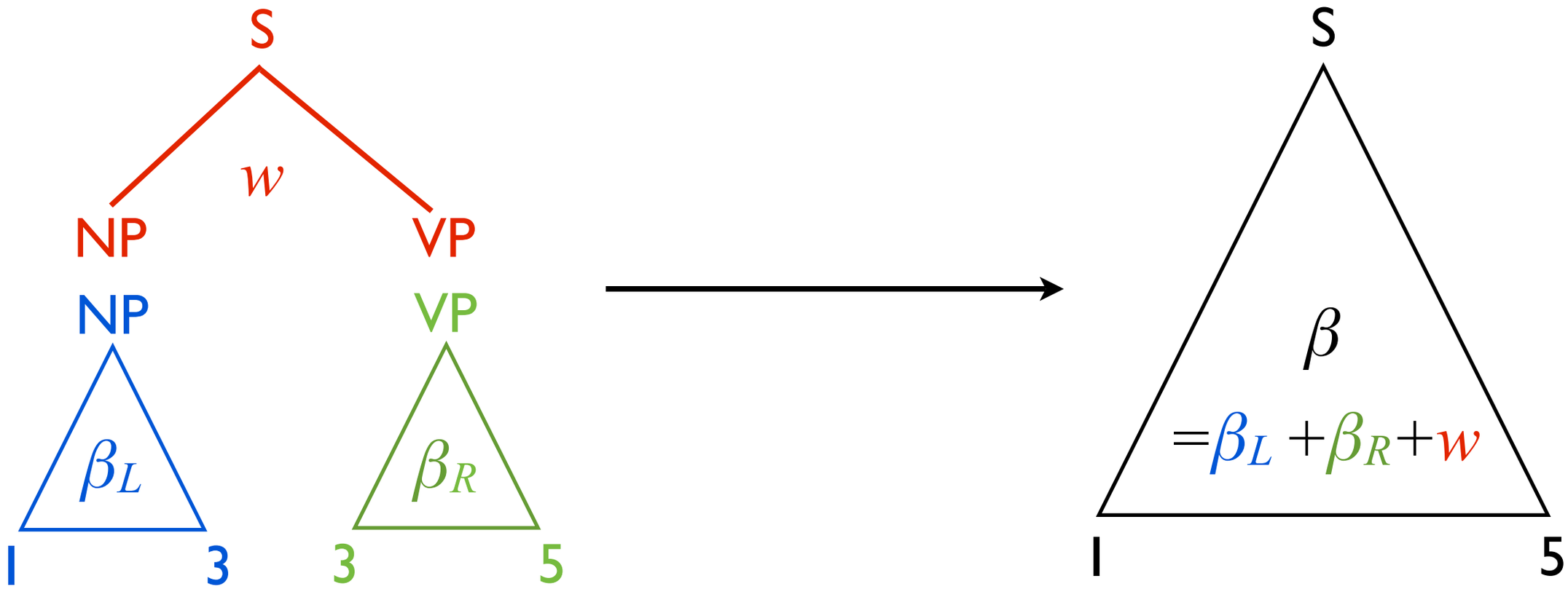

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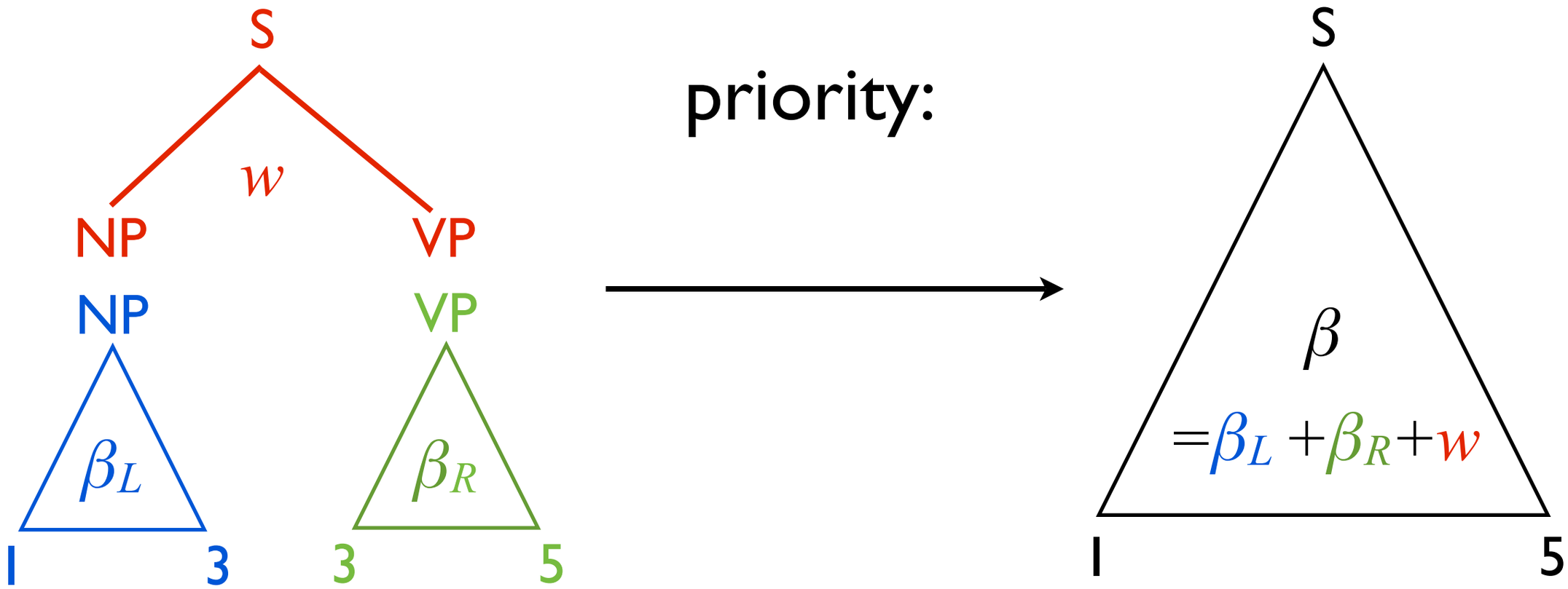

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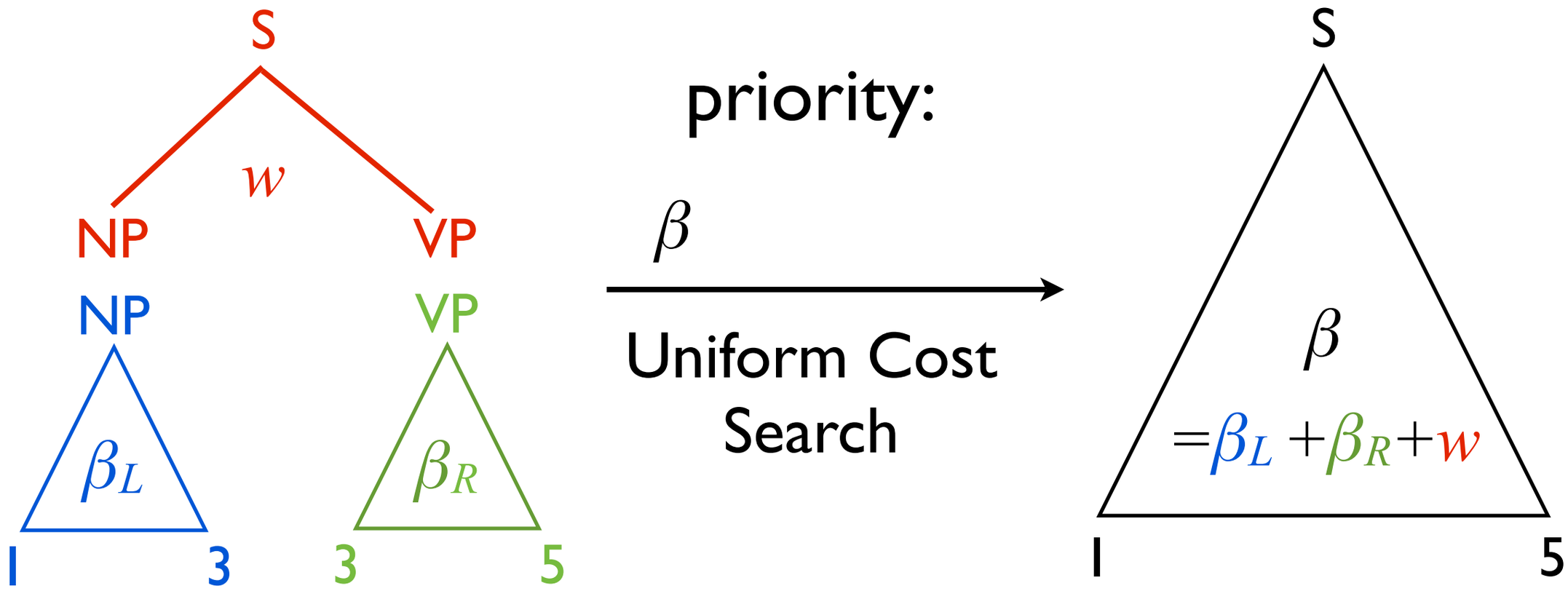

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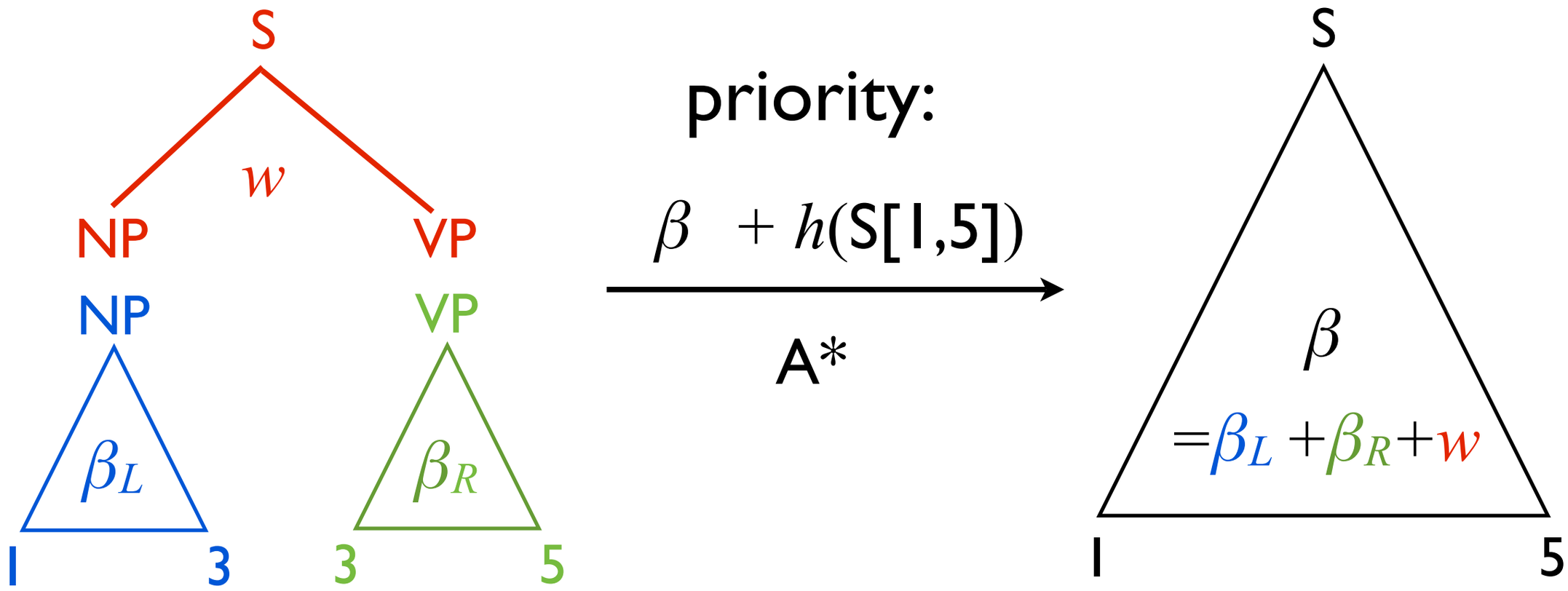

Heuristics

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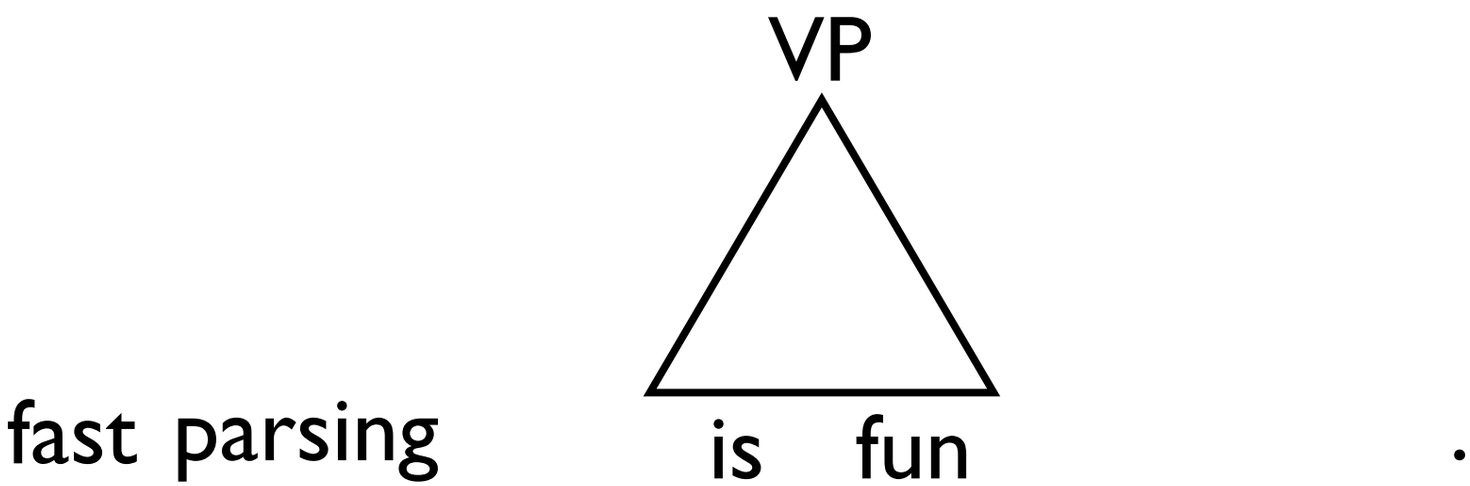

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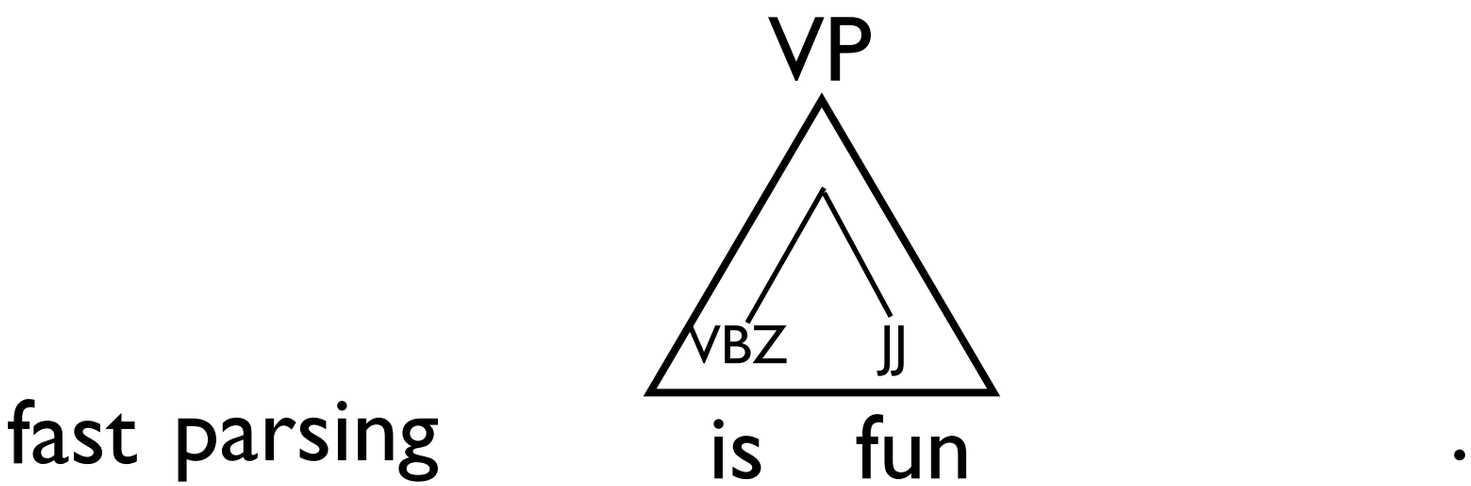

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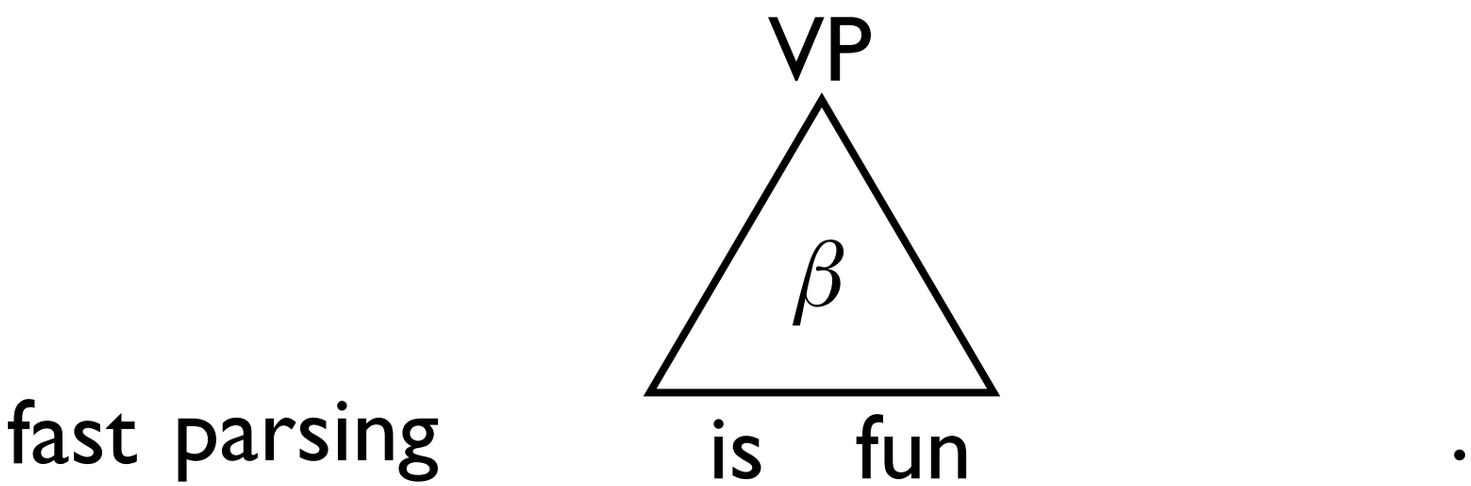

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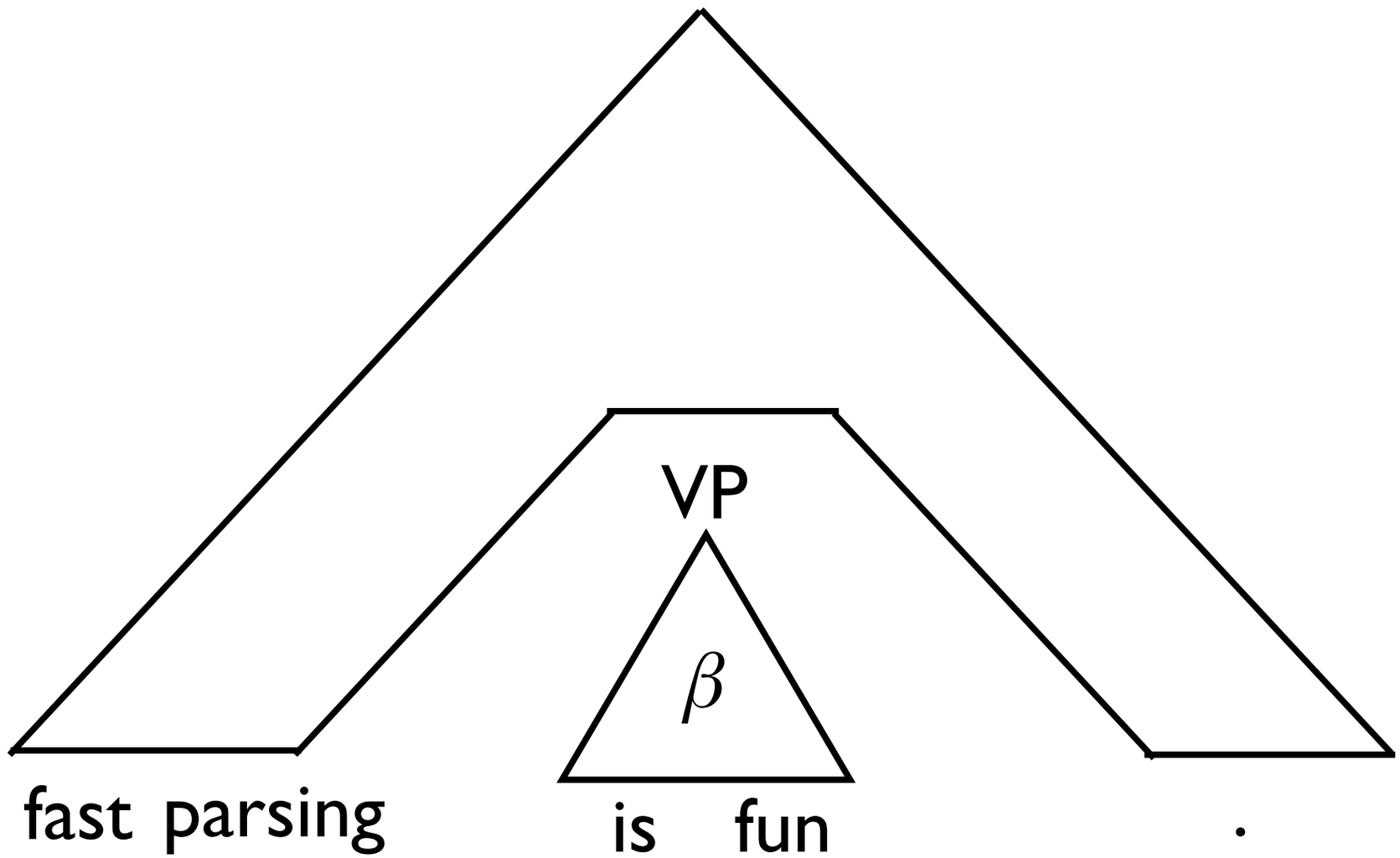

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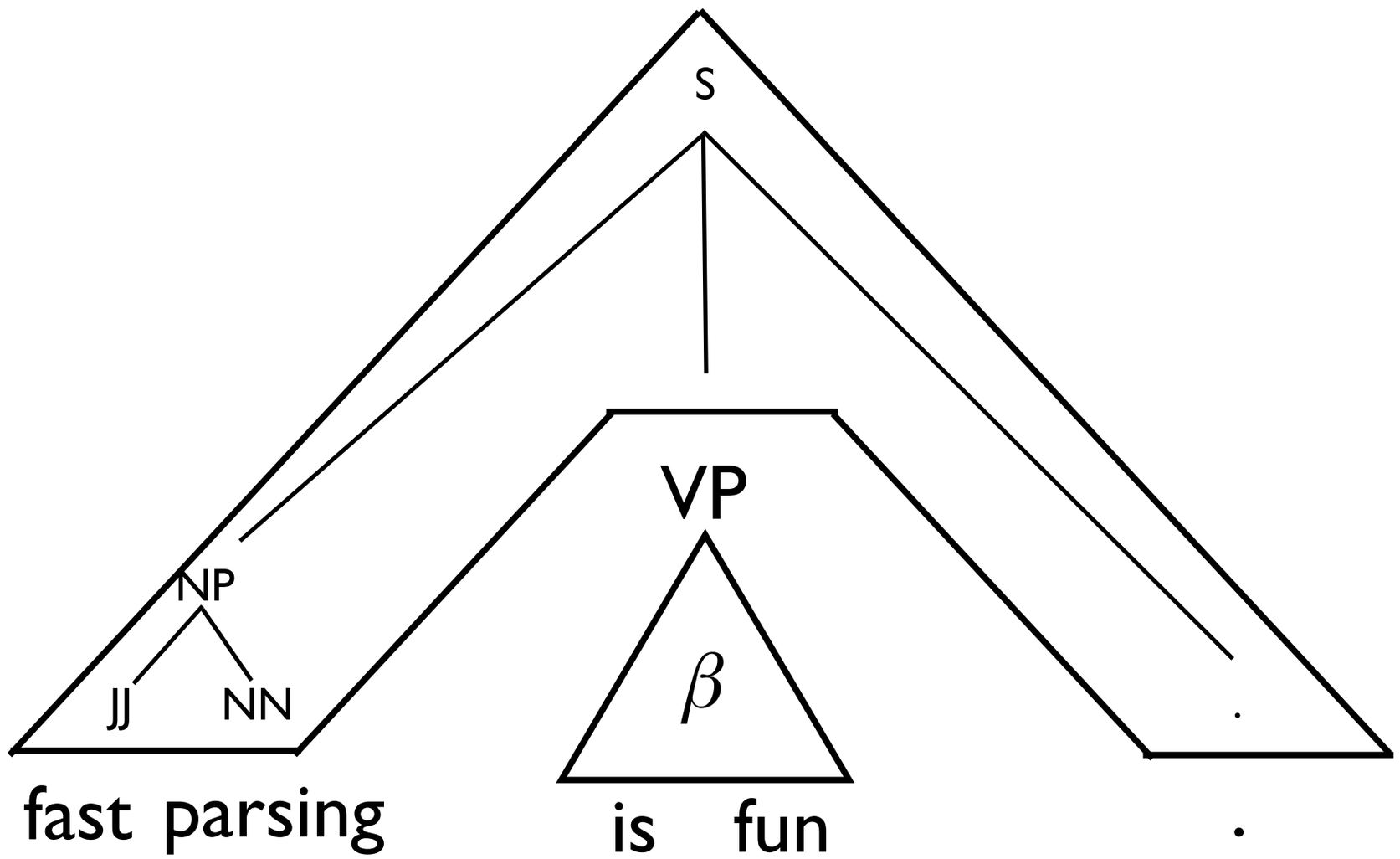

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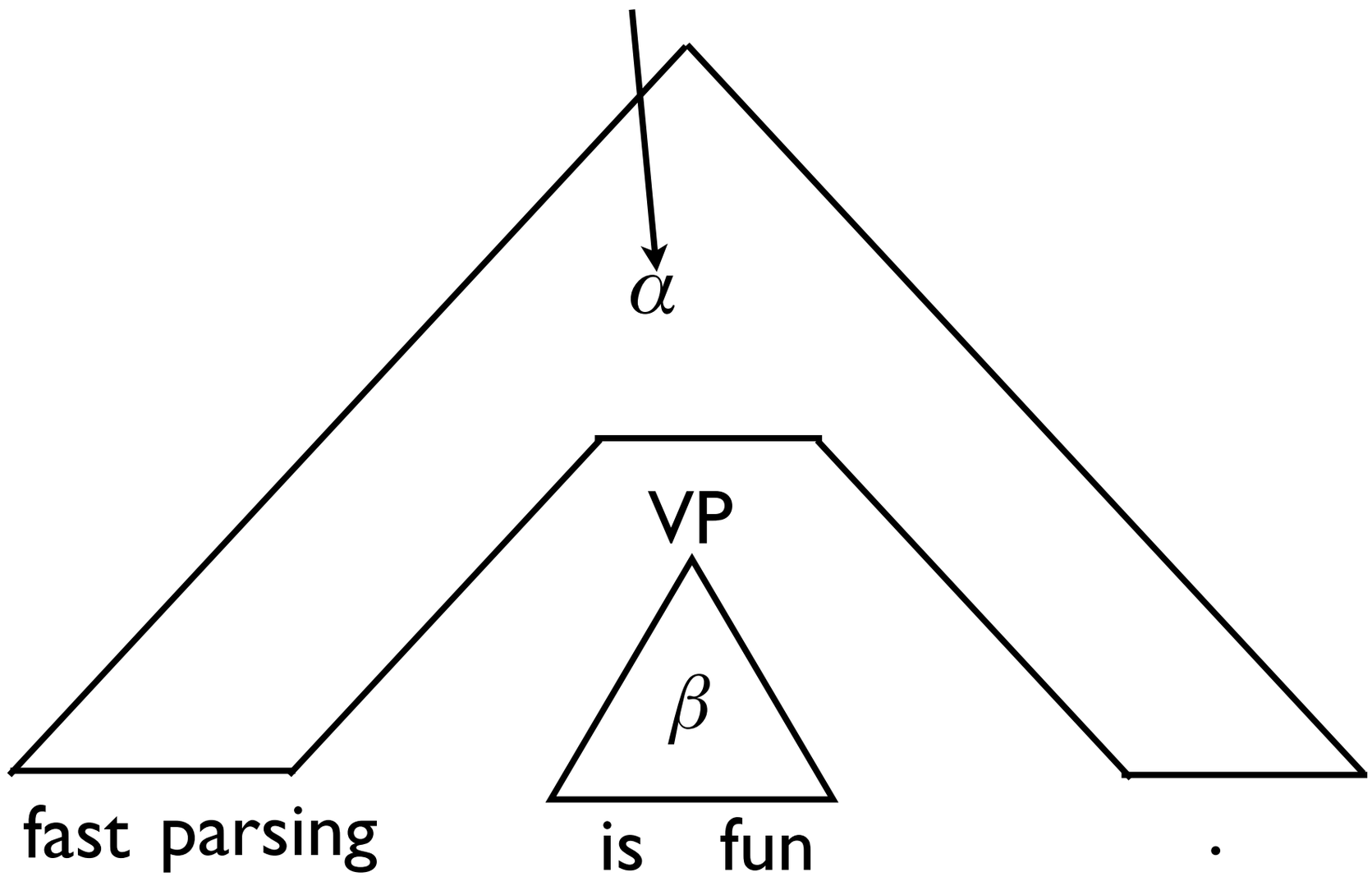

Outside Scores

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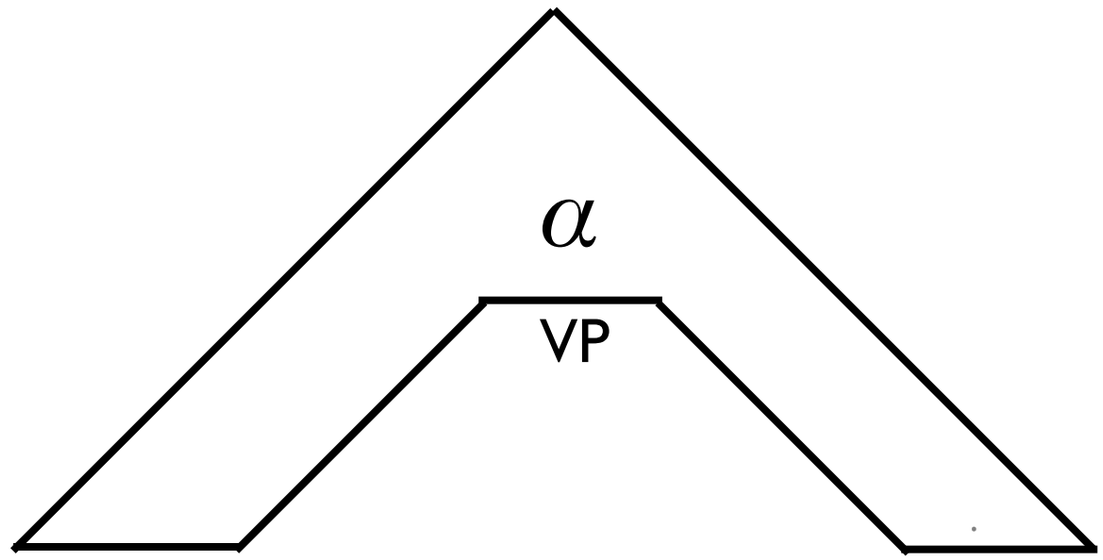

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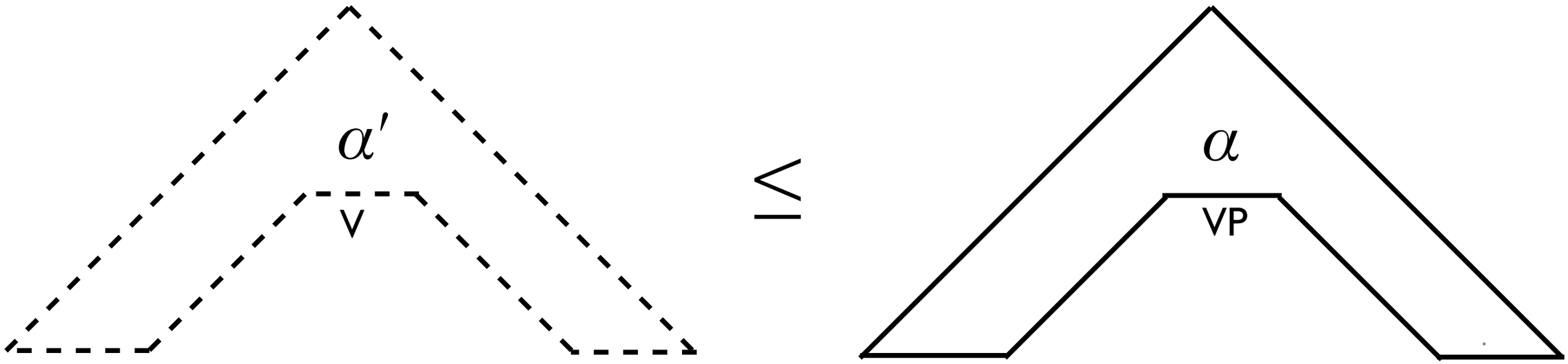

coarse fine

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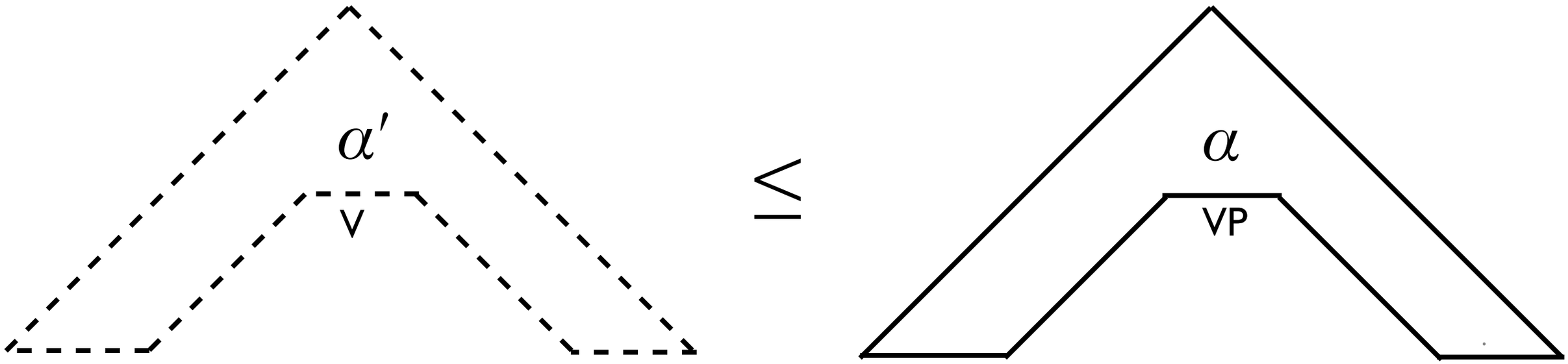
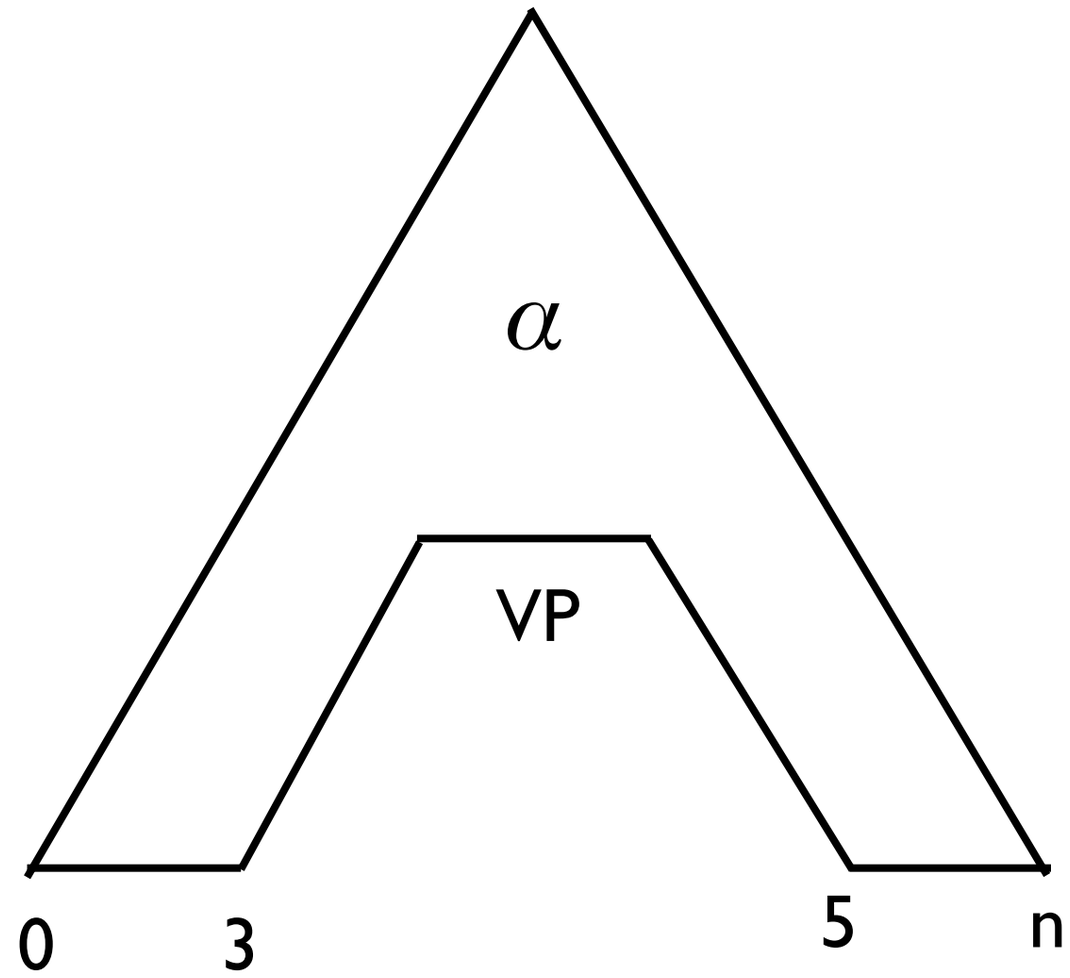


coarse fine

- How do we compute these outside scores?

Building Outside Edges



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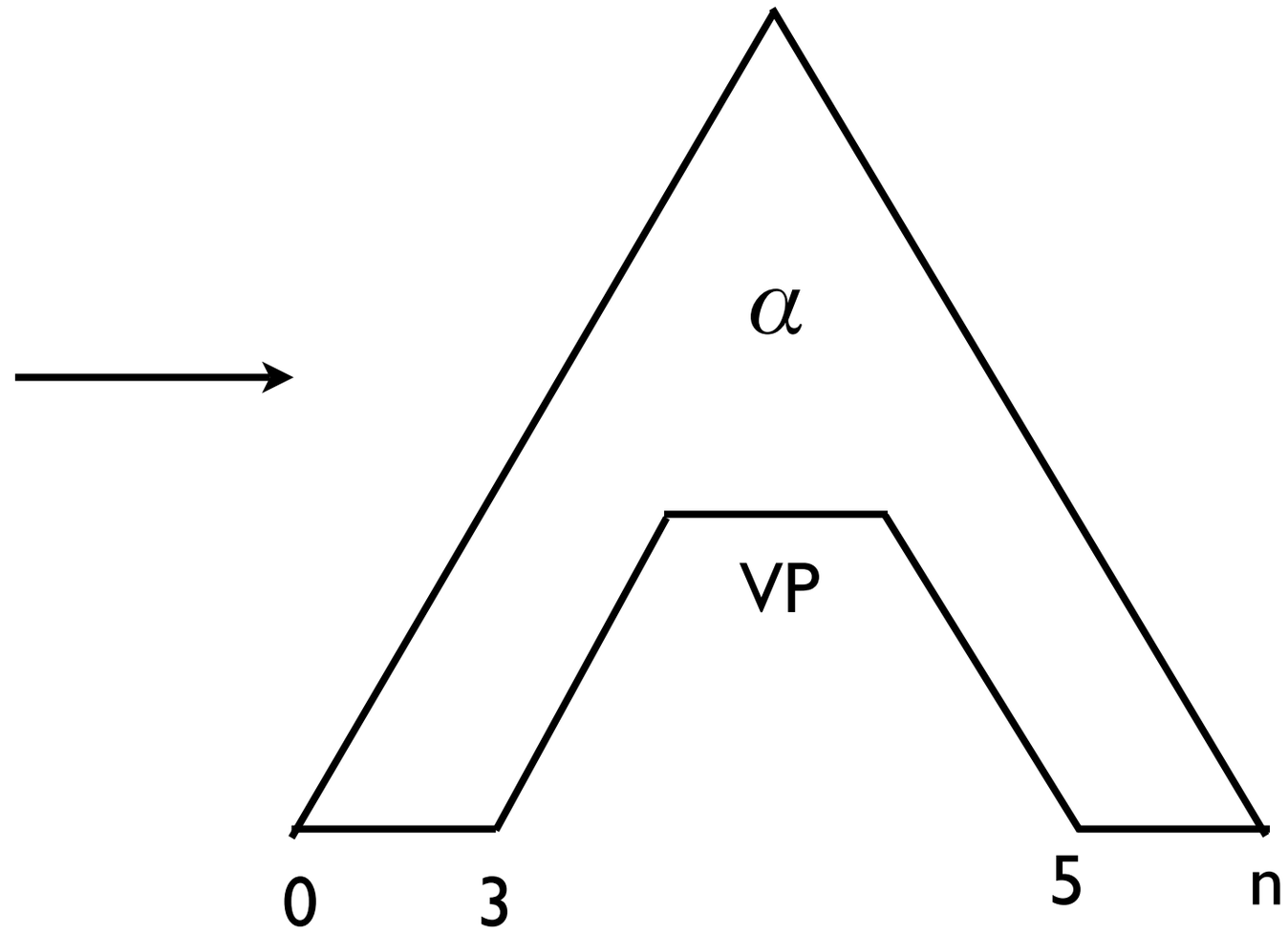

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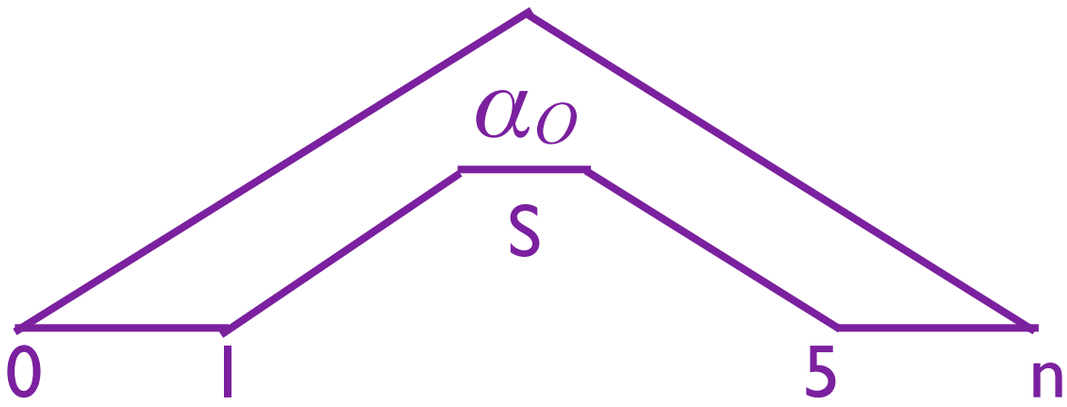

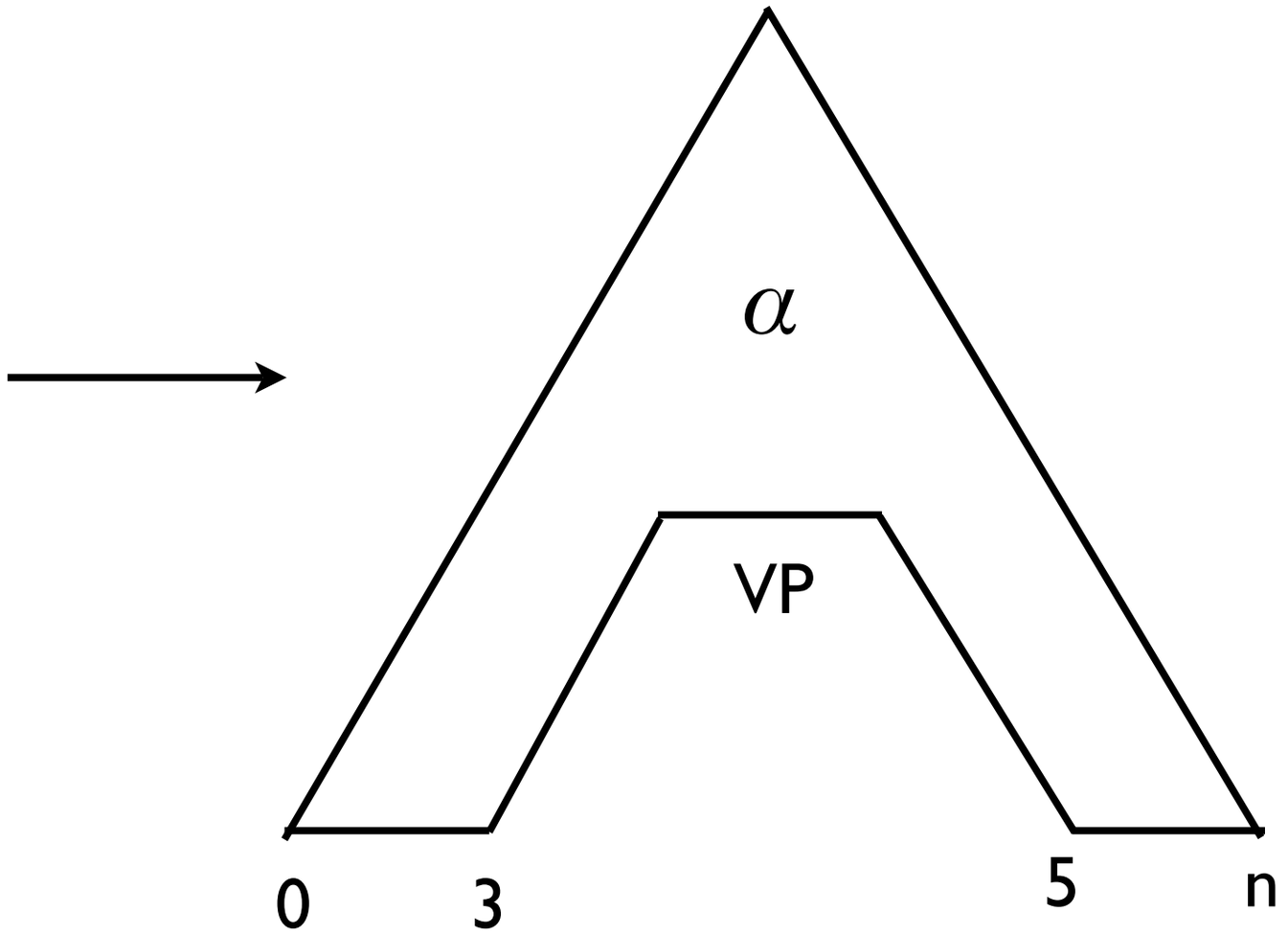

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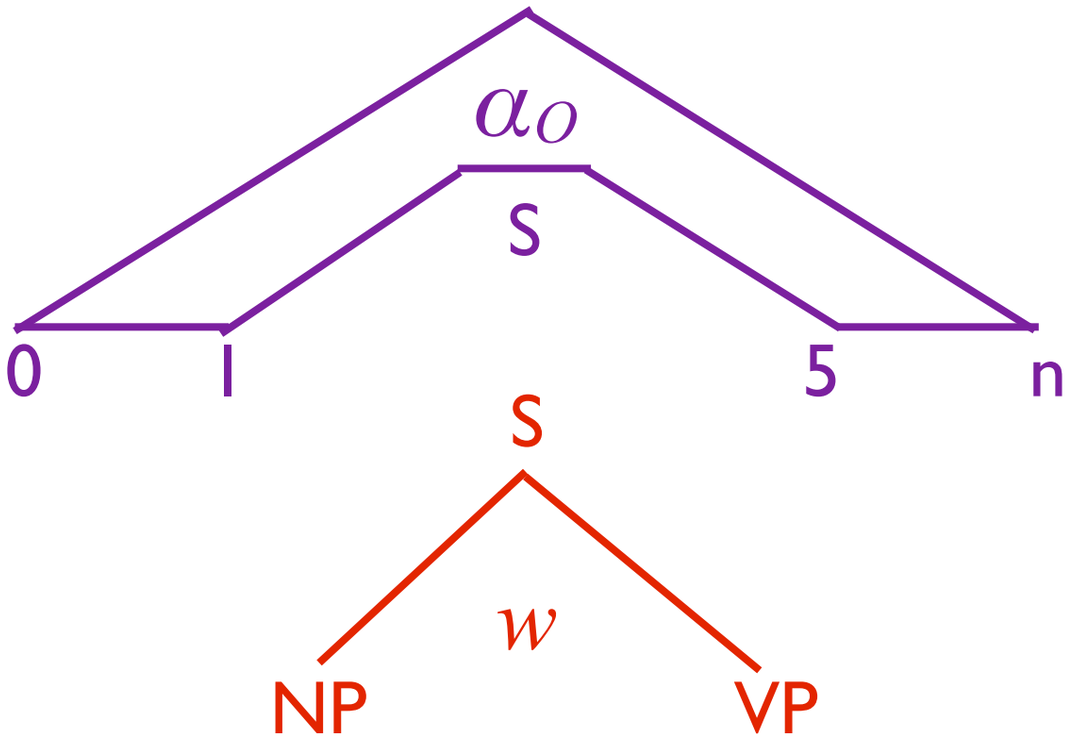

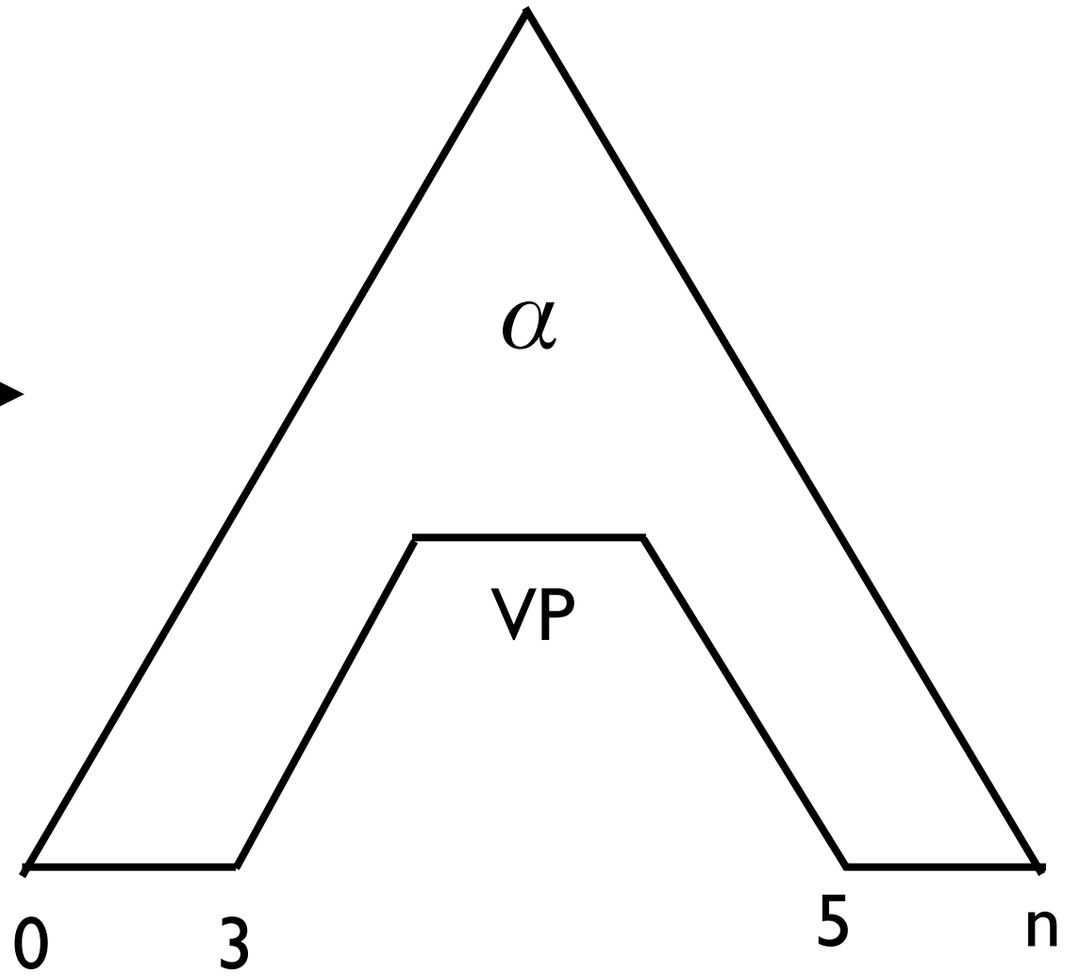

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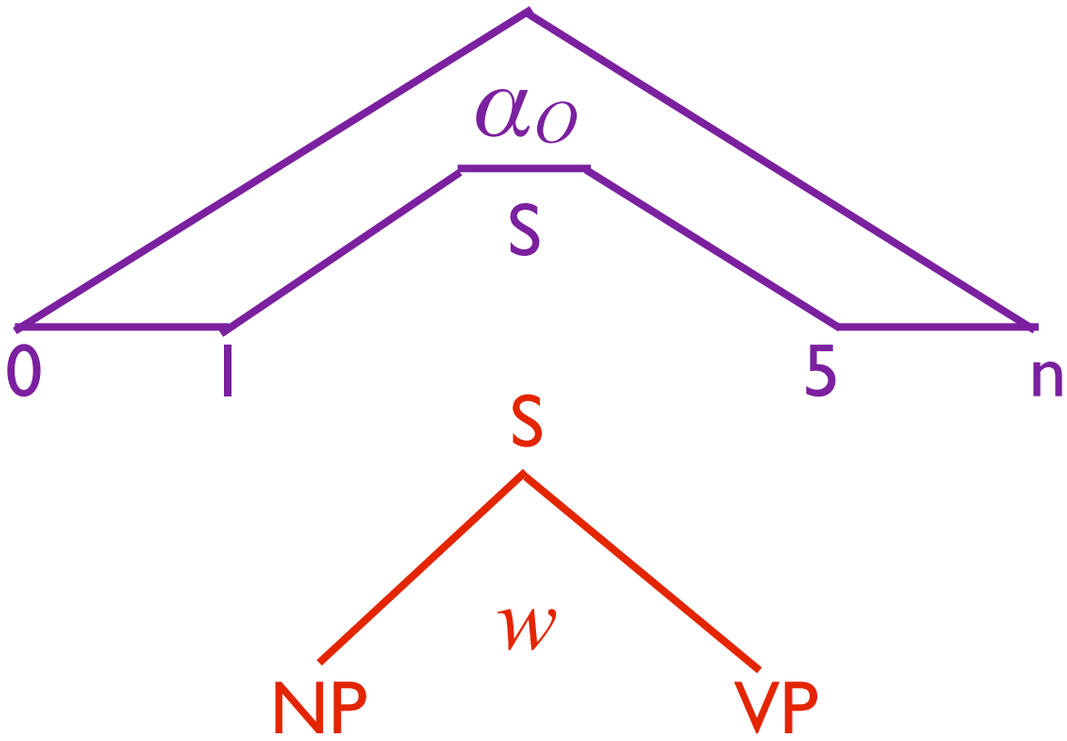

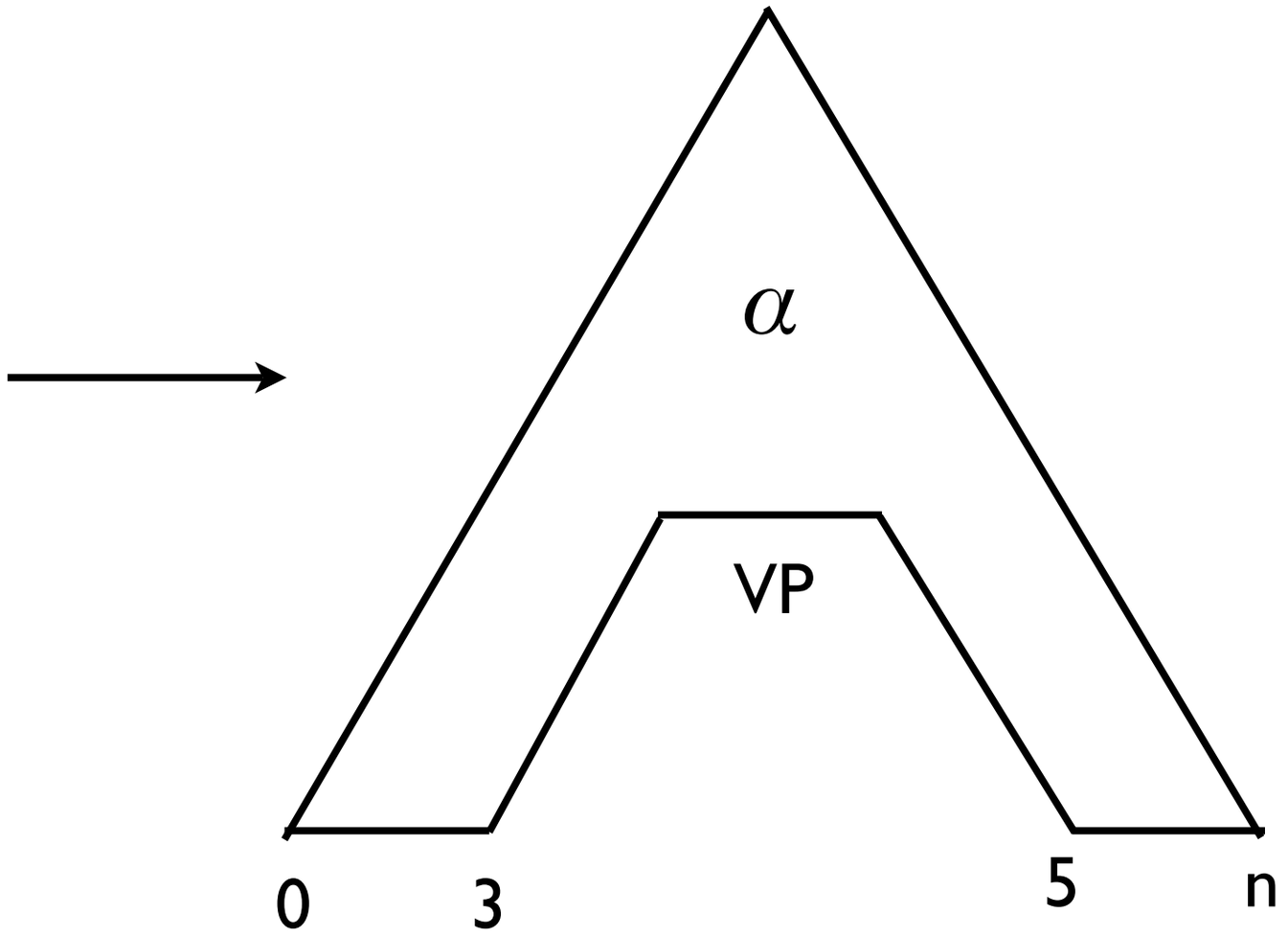

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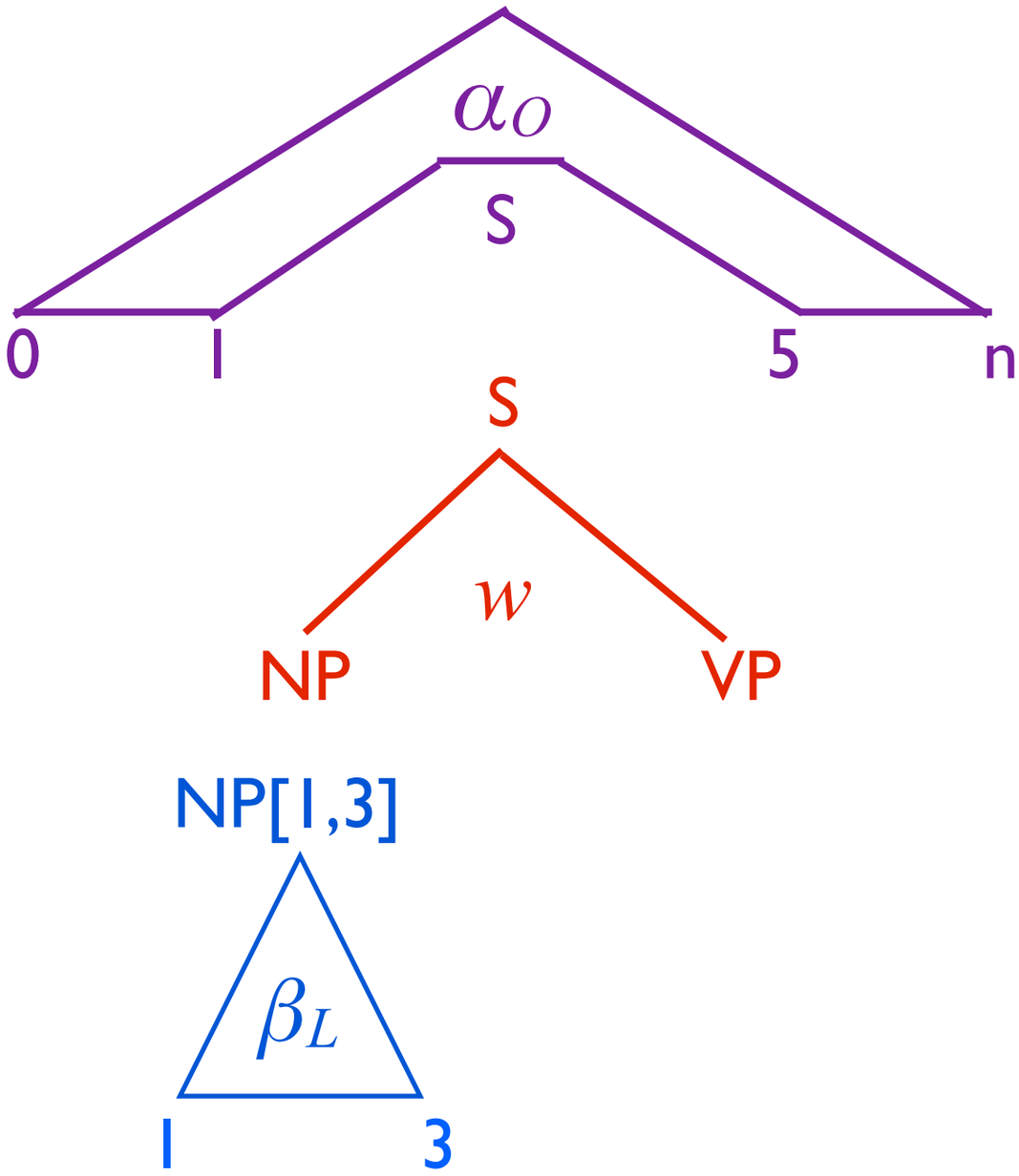
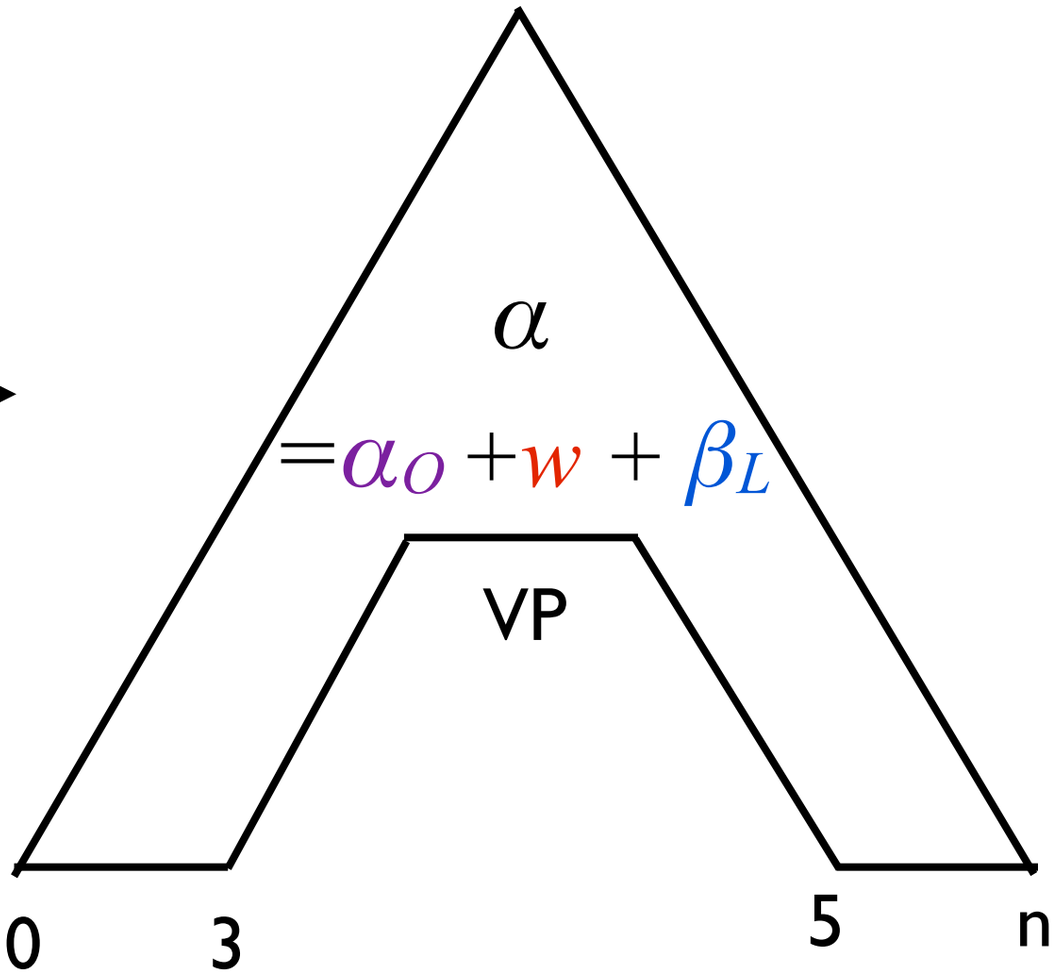
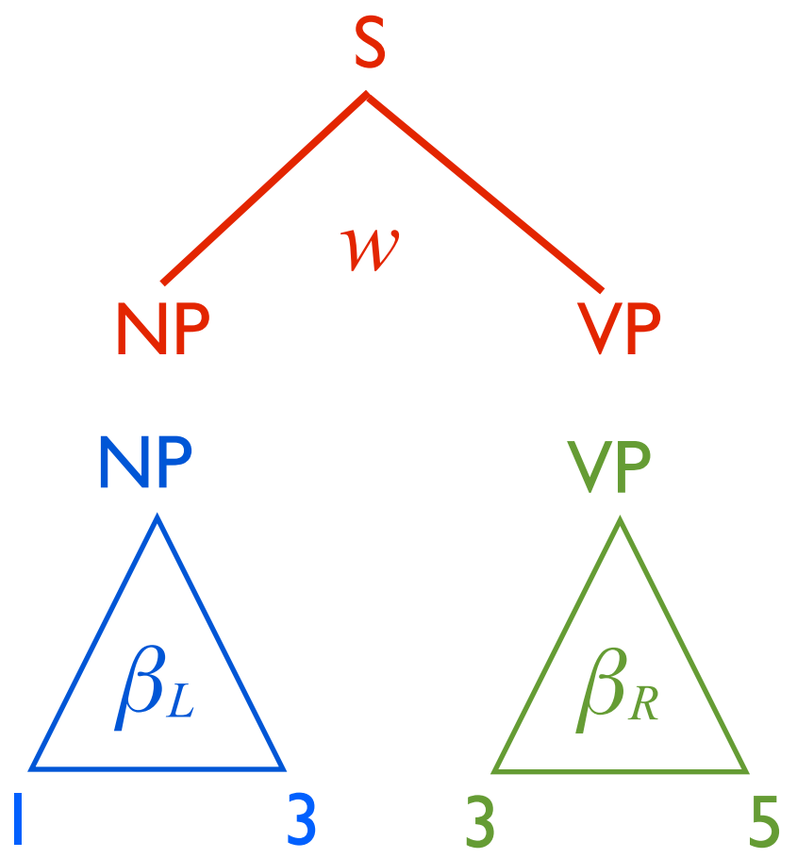




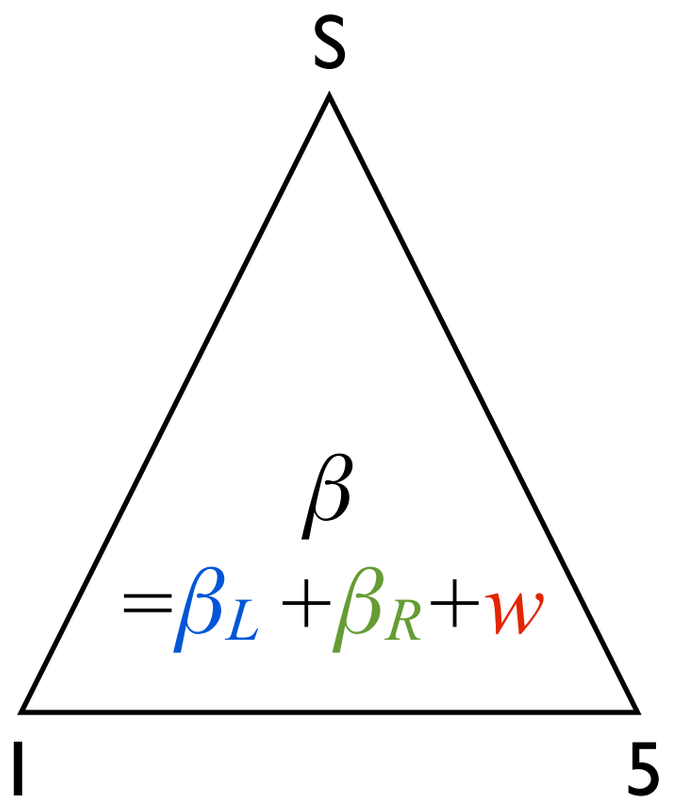
Hierarchical A* (Felzenswalb and McAllester 2007)

- Basic Idea:
  - build both inside and outside edges as needed using same agenda
  - use coarse outside scores as heuristics for fine inside edges

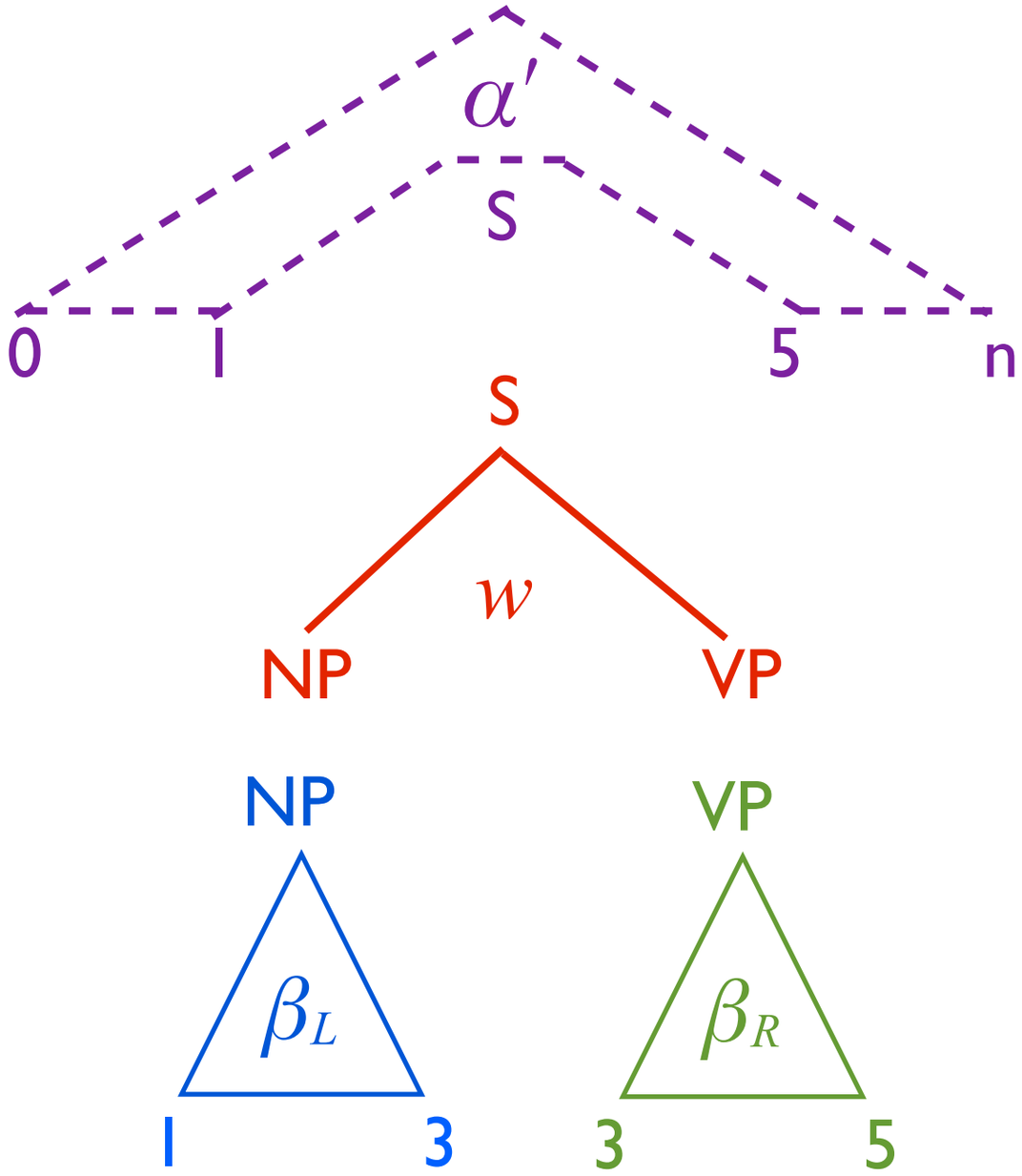
Hierarchically Building Inside Edges



$\beta + h(\mathrm{S}[1,5])$



Hierarchically Building Inside Edges



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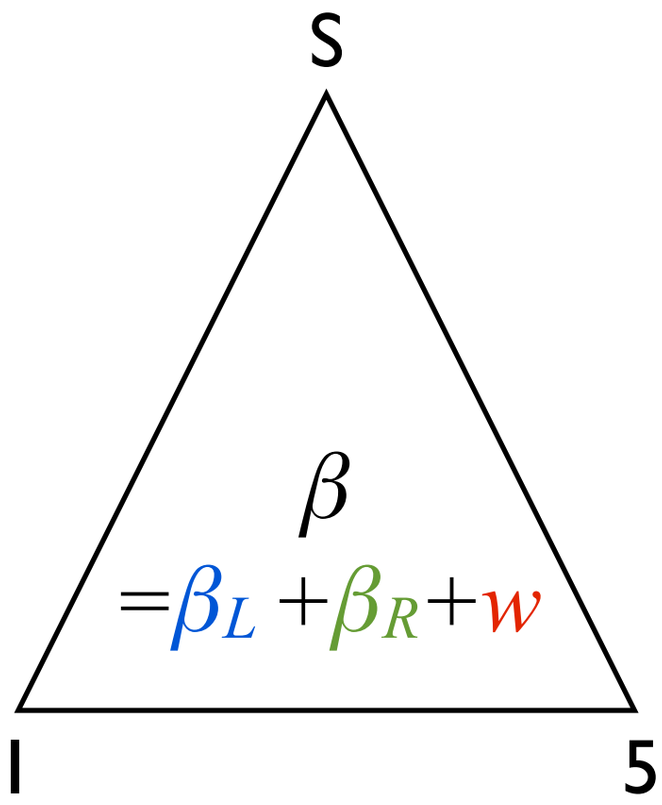

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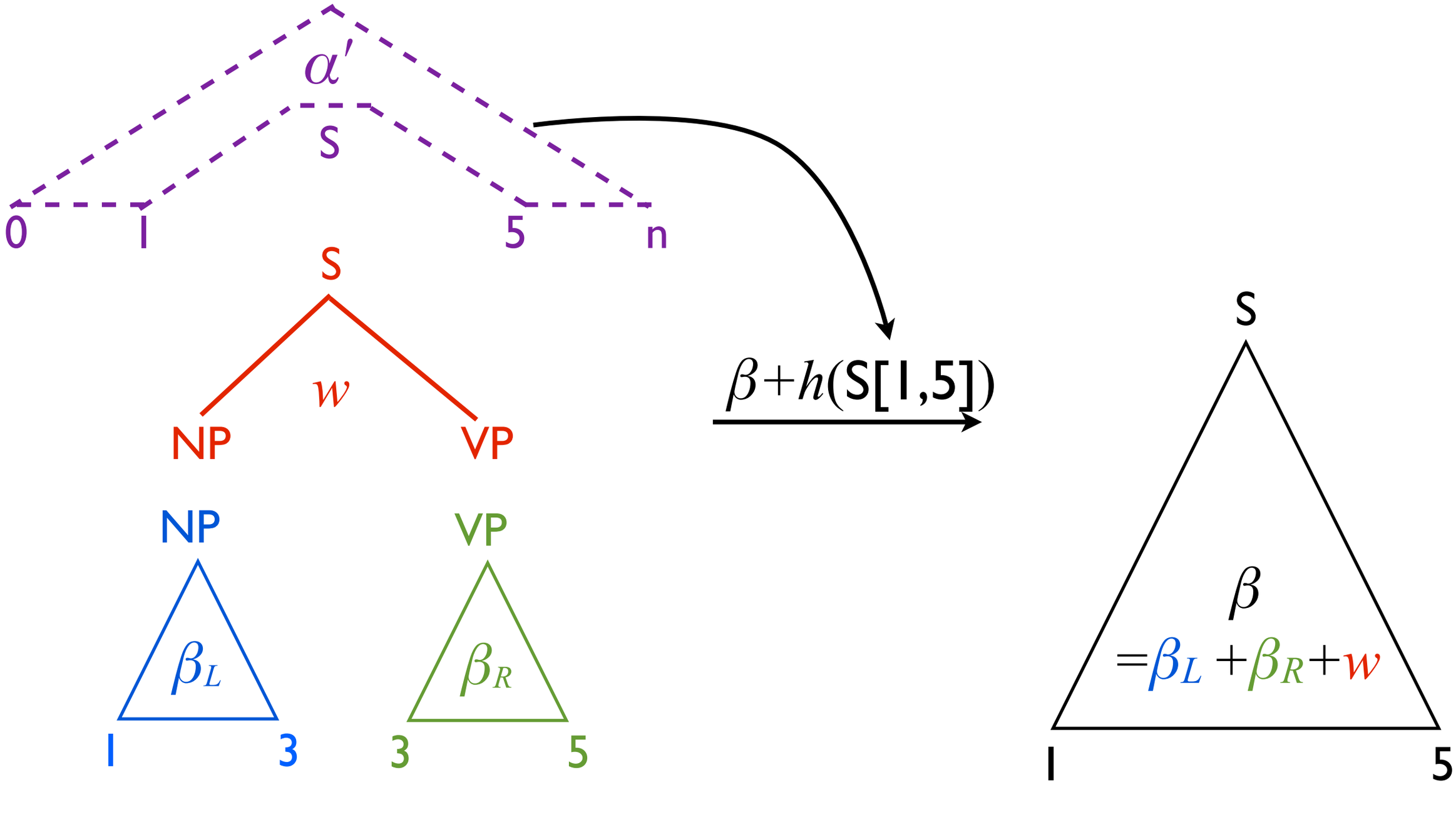

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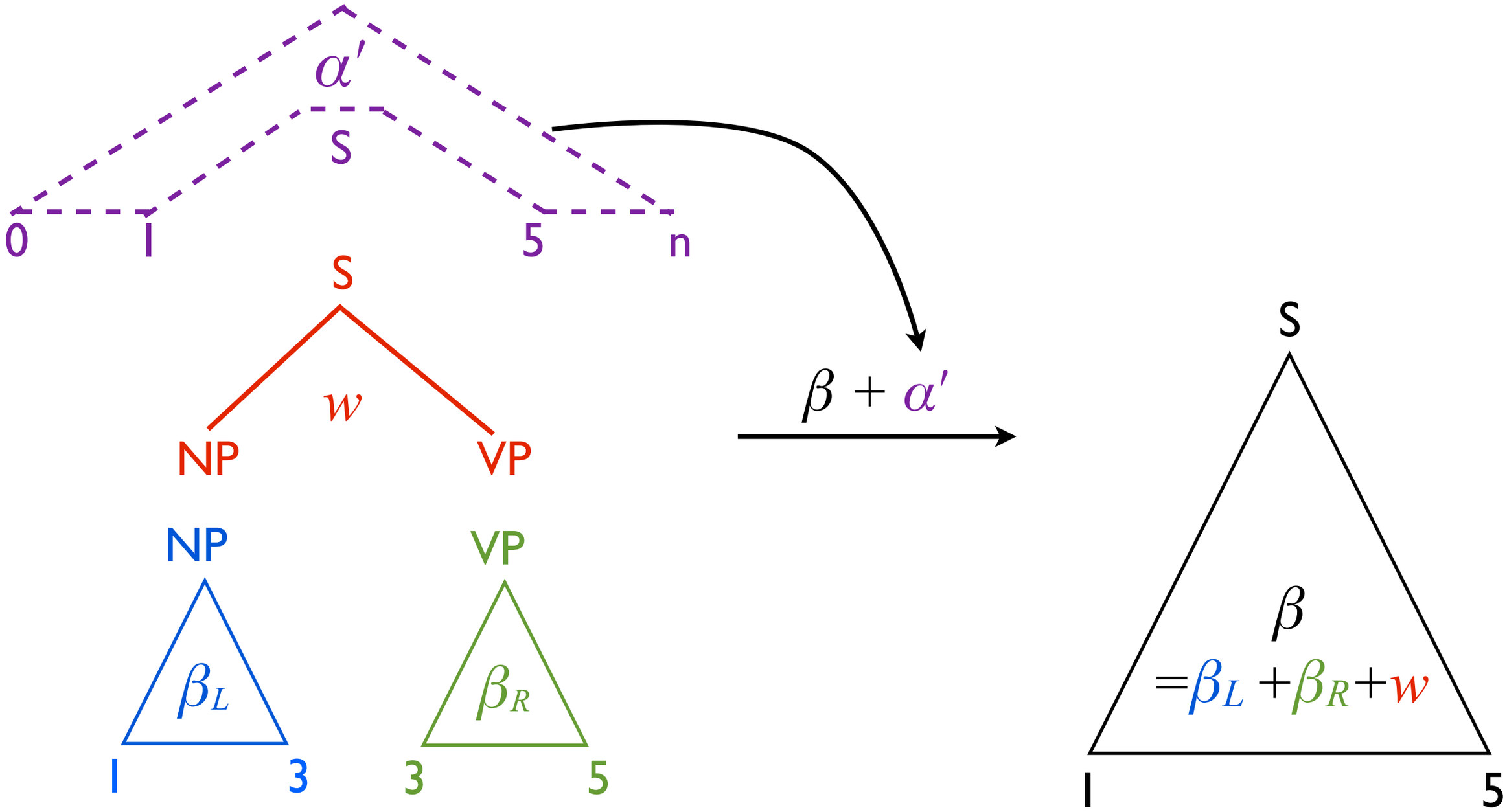

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HA*

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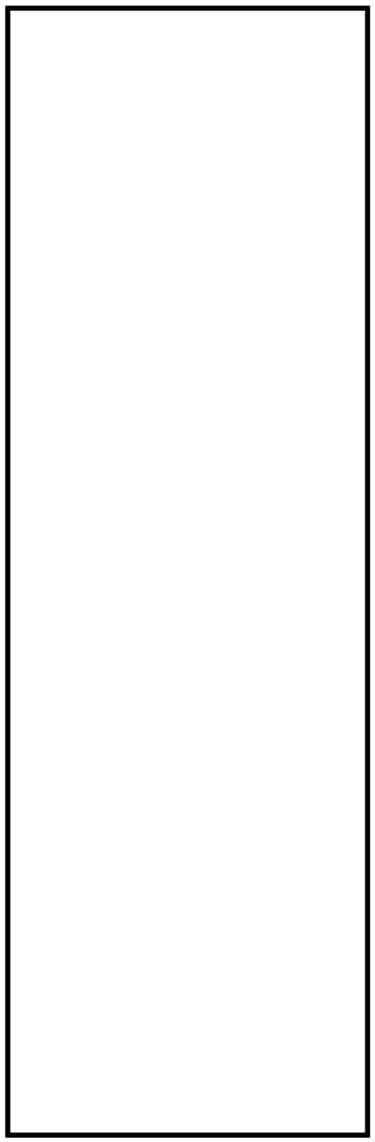

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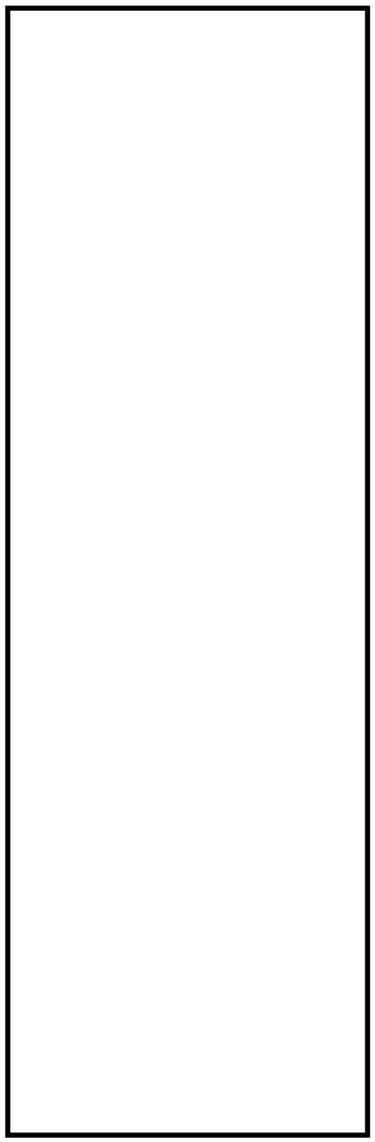
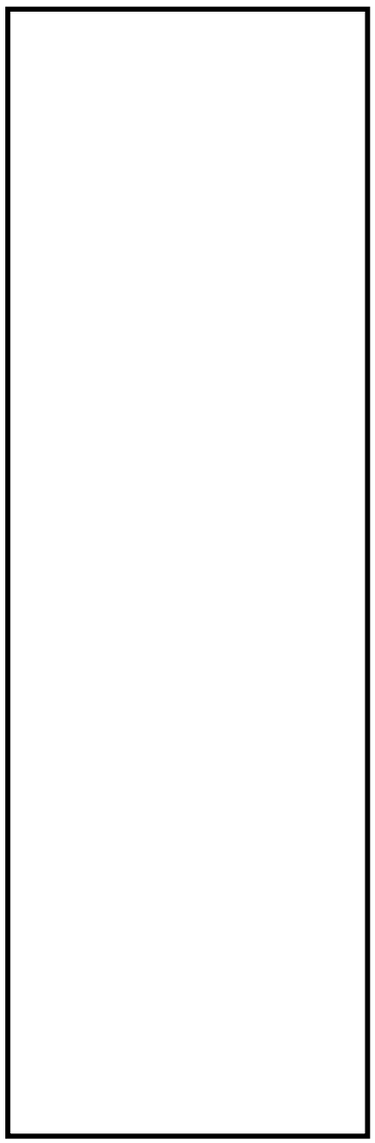


Agenda

Charts

HA*

inside



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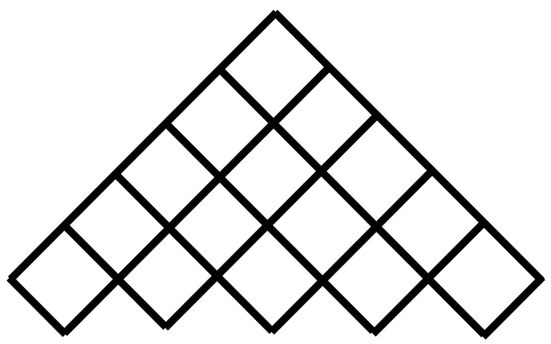

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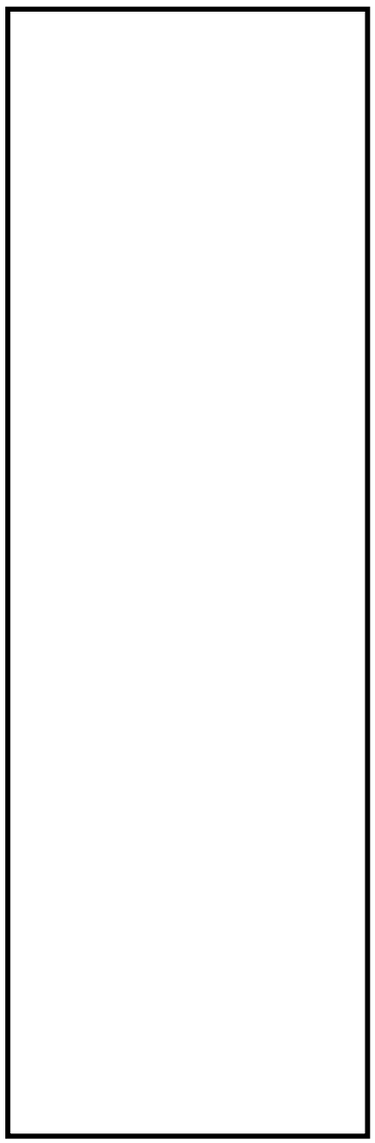
inside

outside



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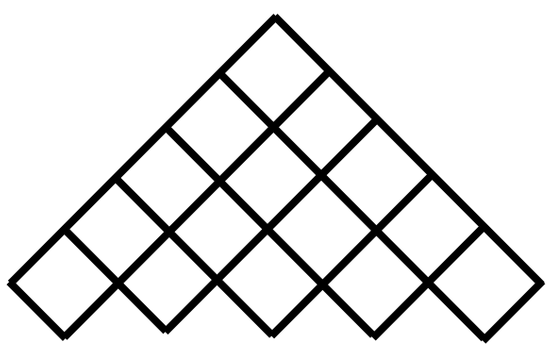
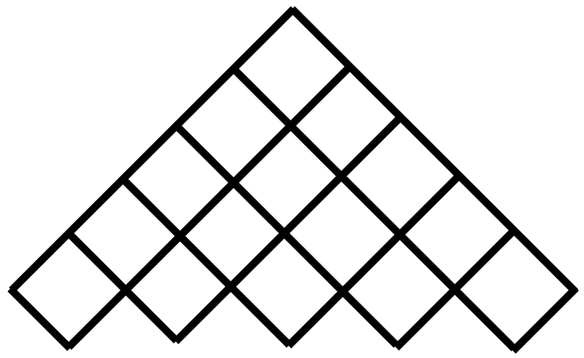
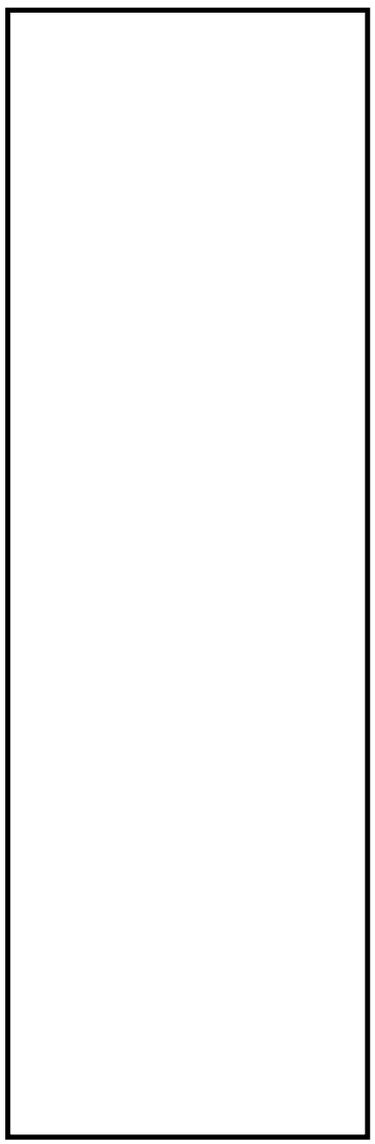




Charts

HA*



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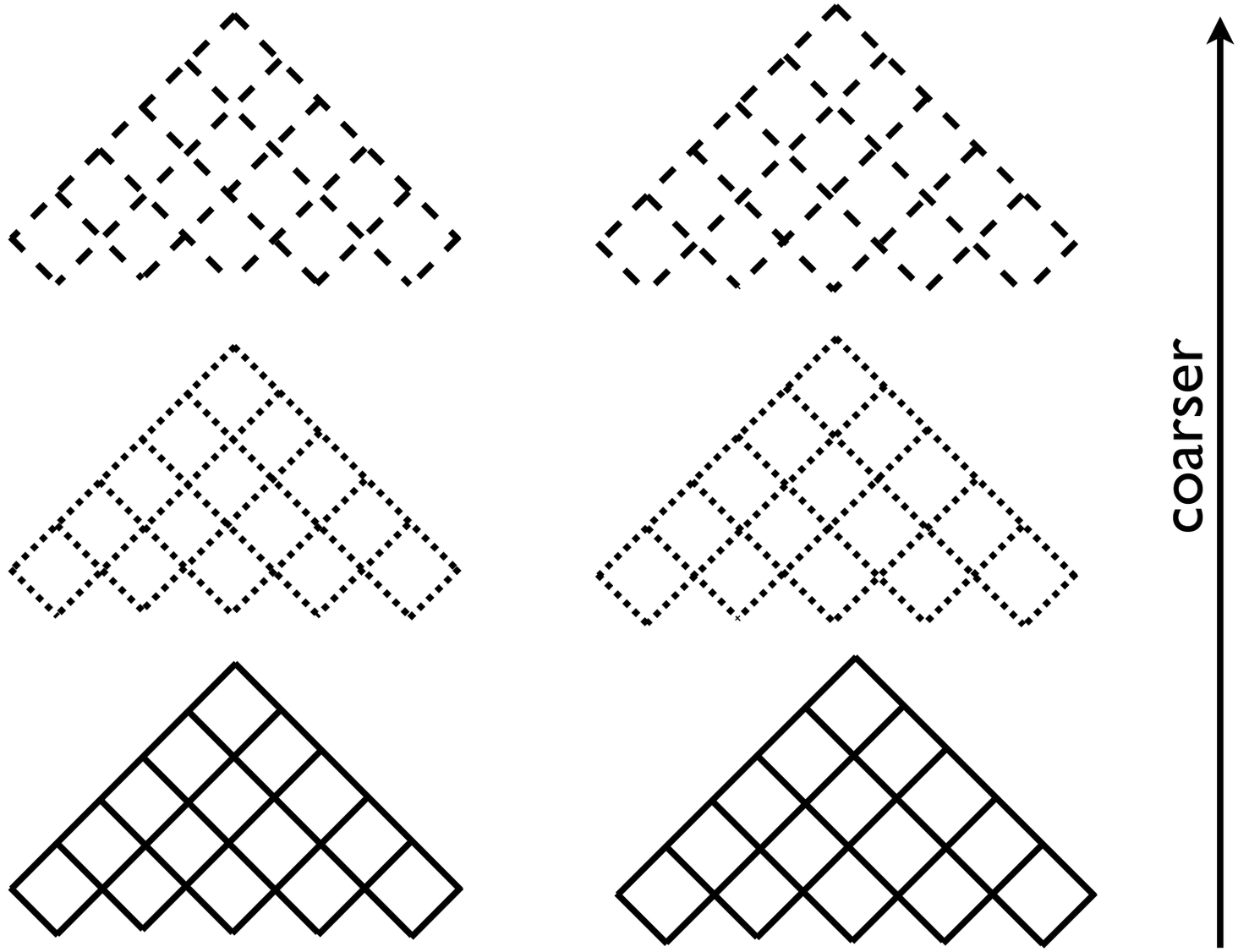

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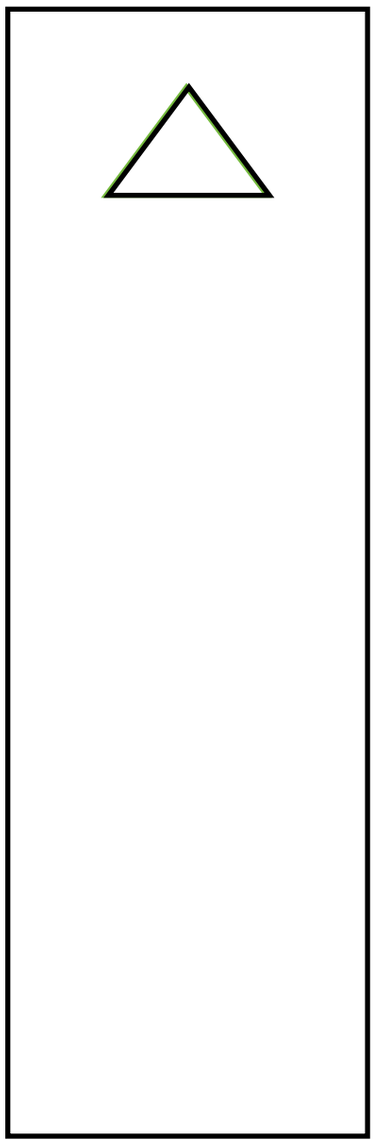

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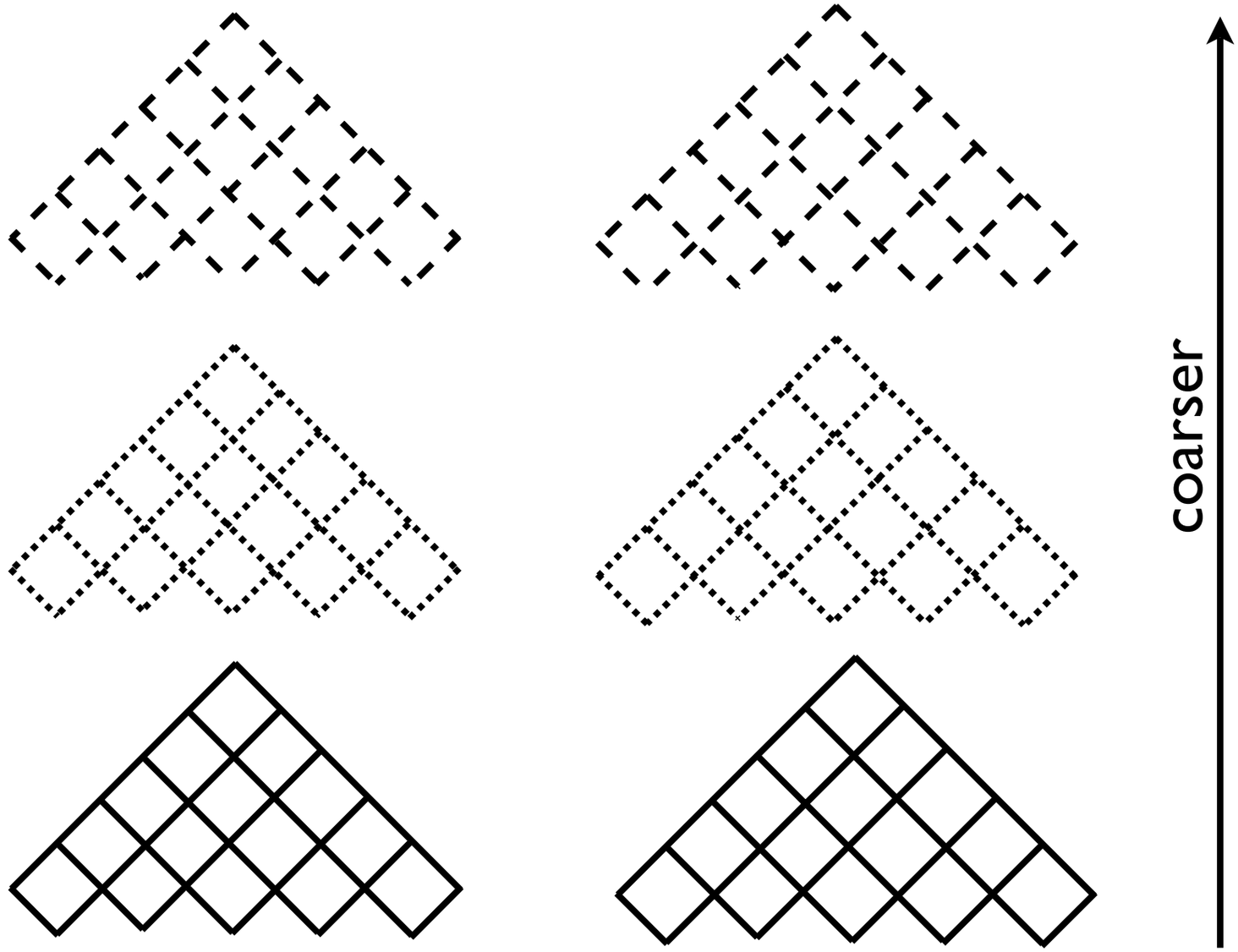

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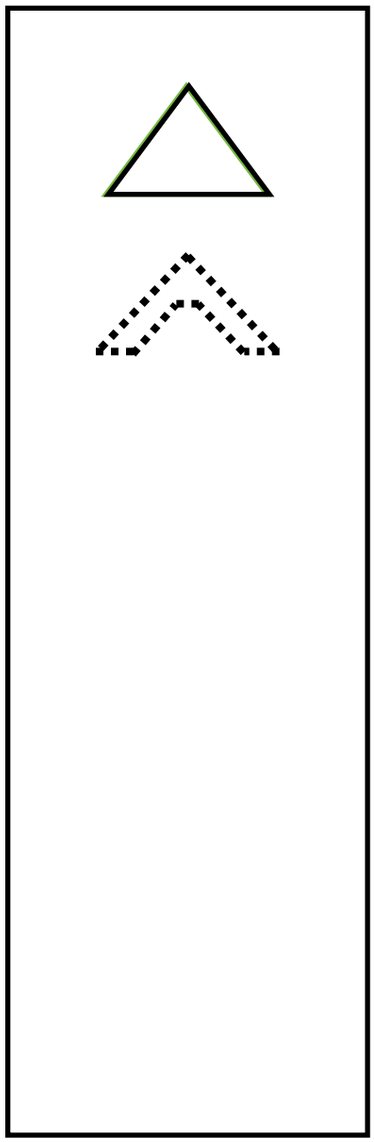

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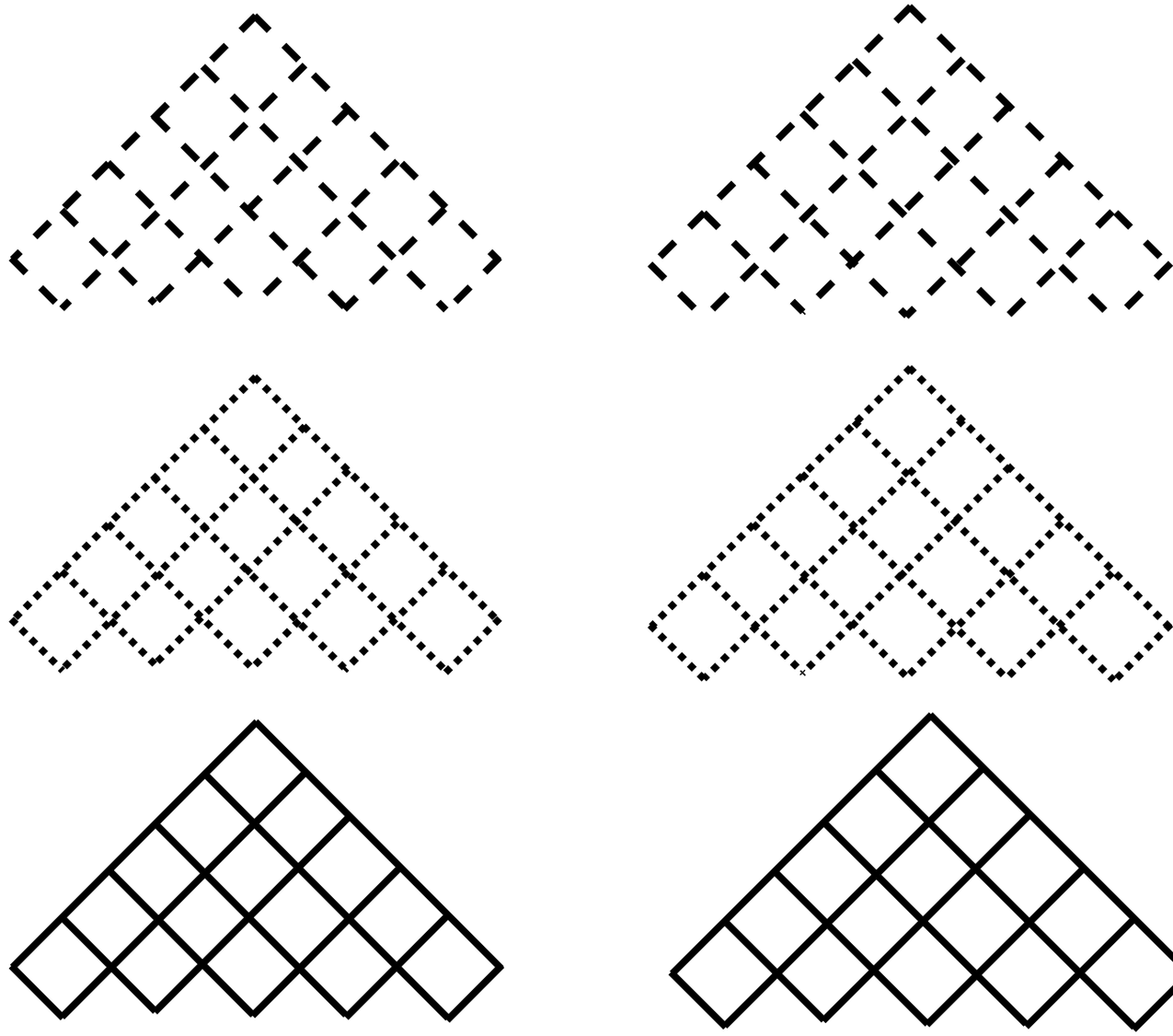
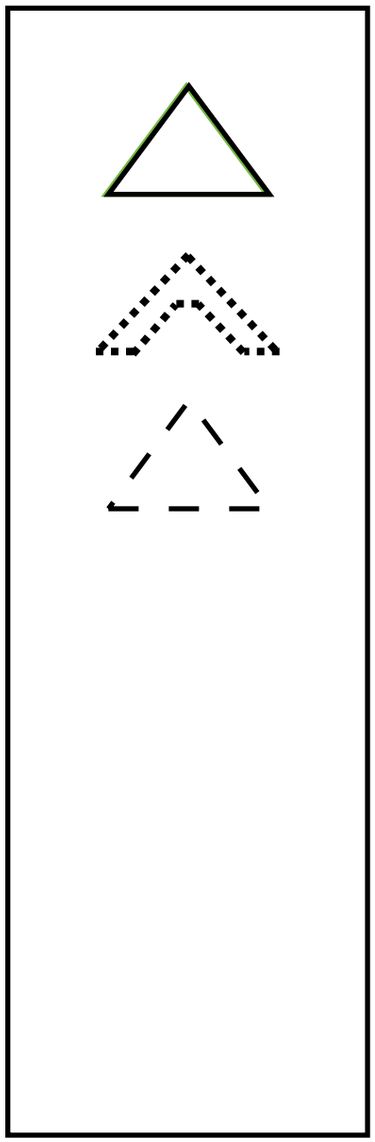


coarser

Charts

HA*



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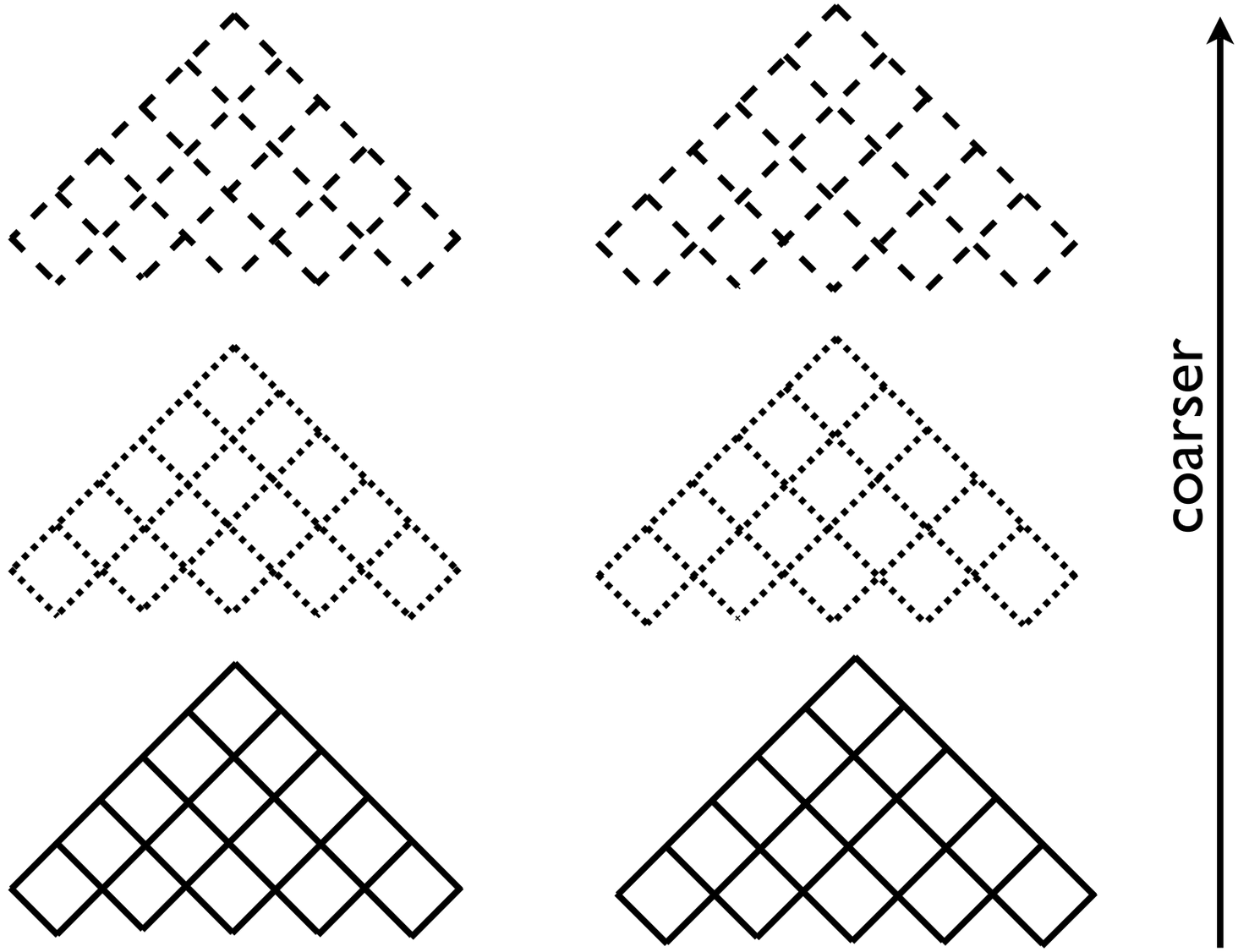

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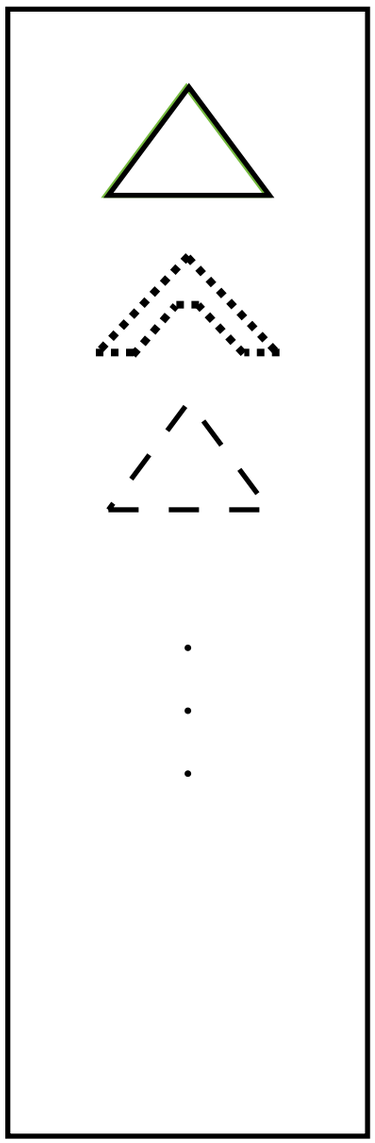

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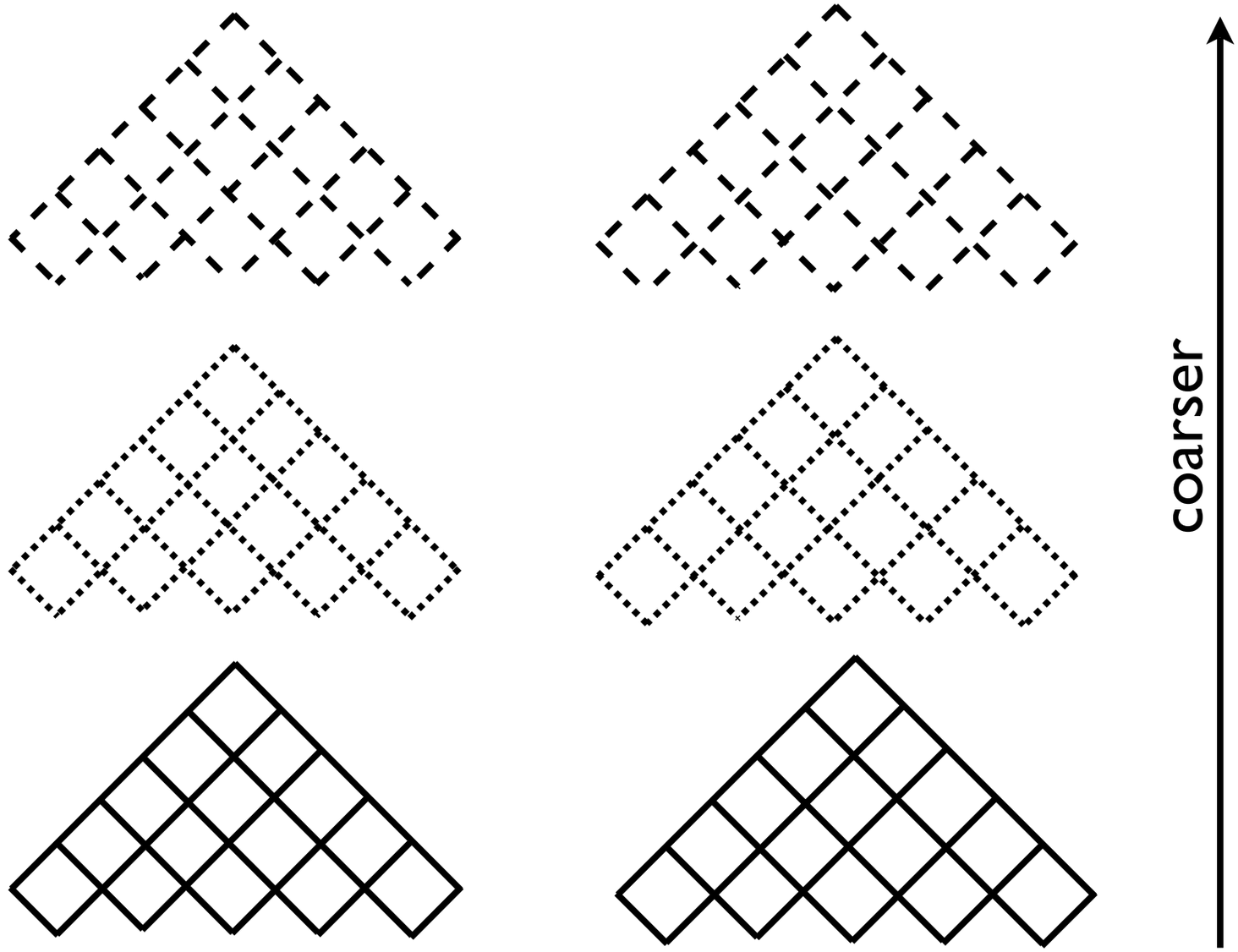

Charts

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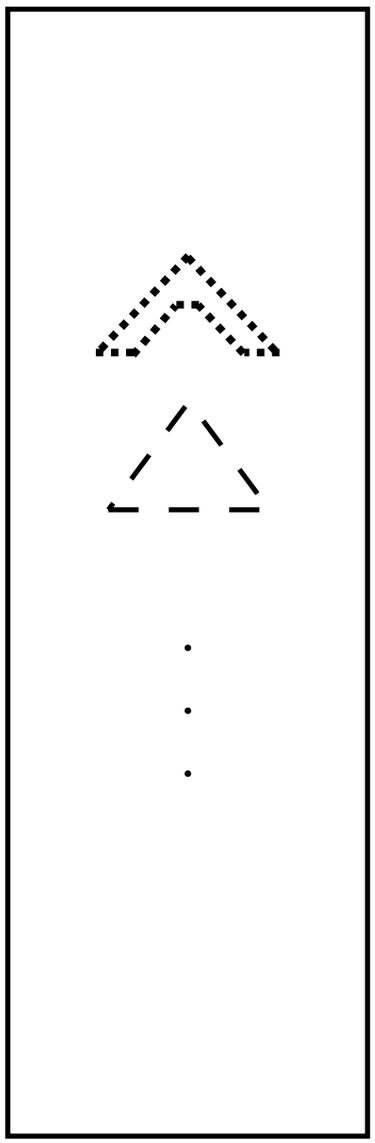

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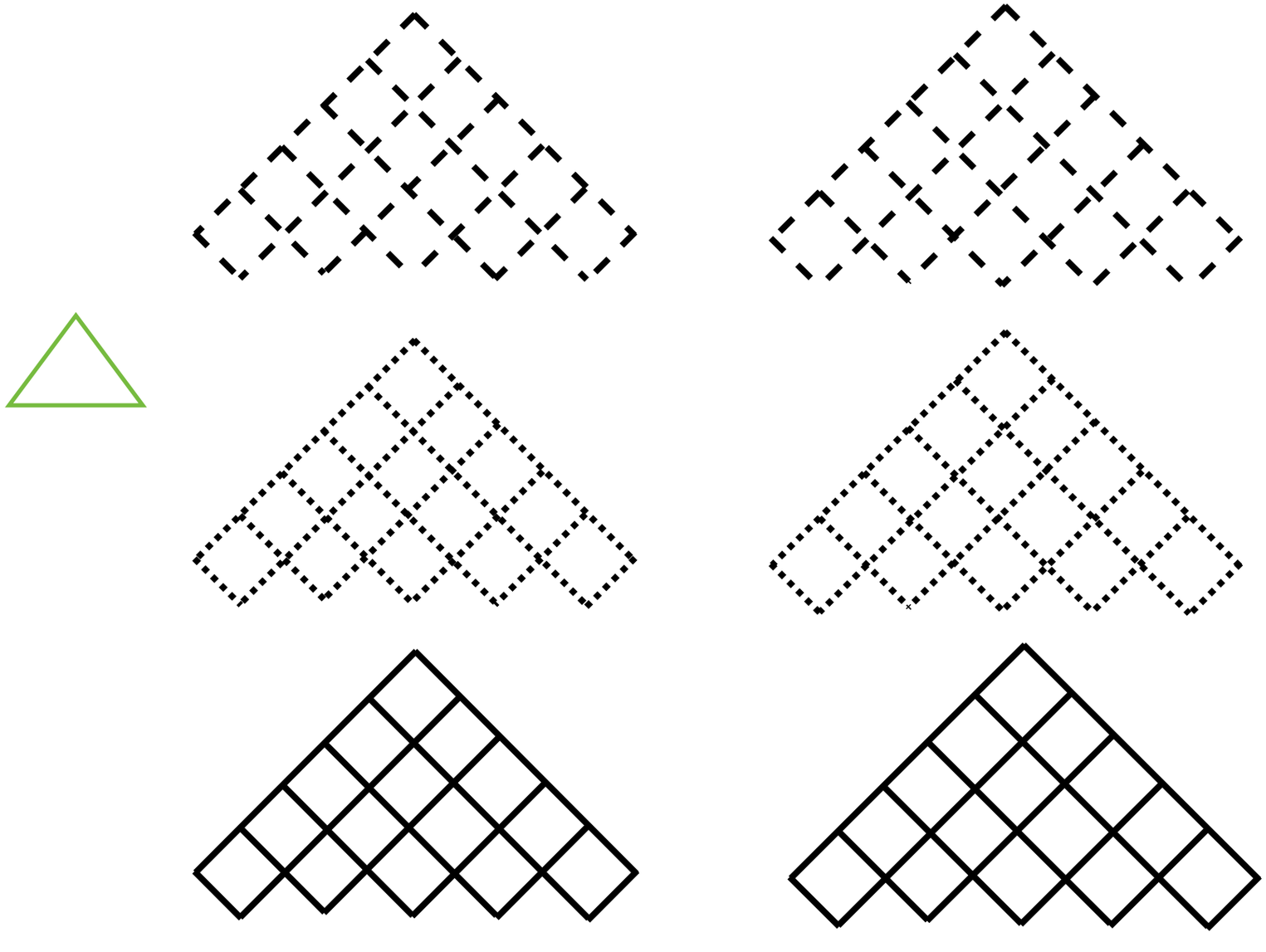

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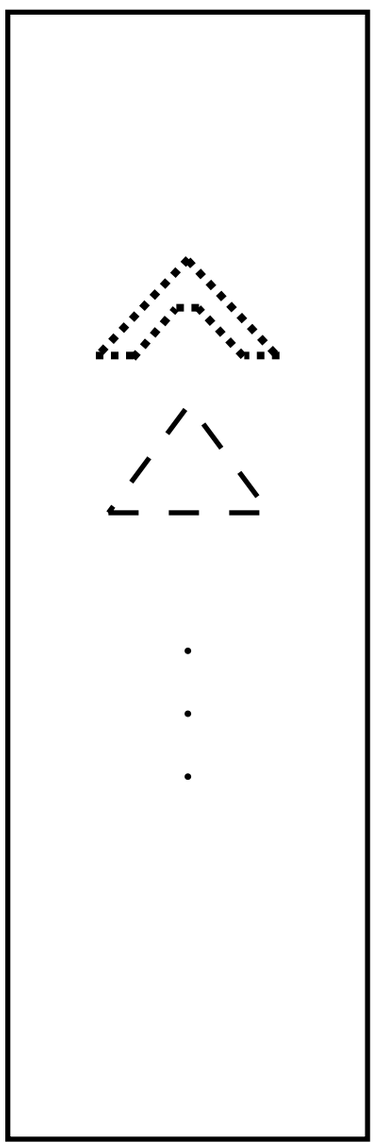

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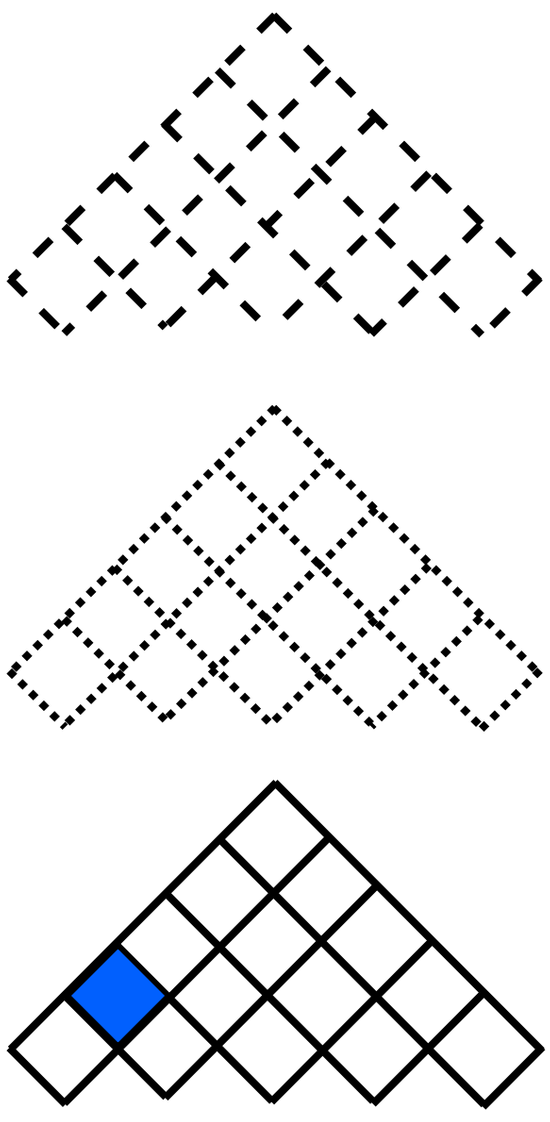

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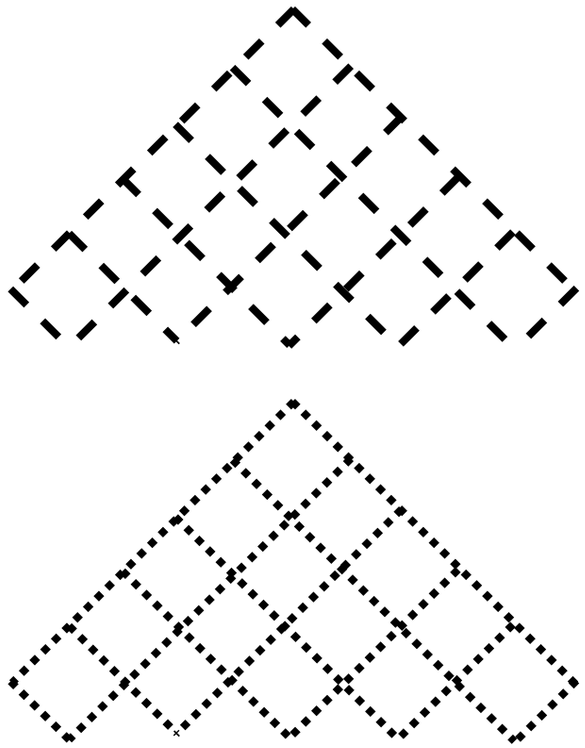

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Charts

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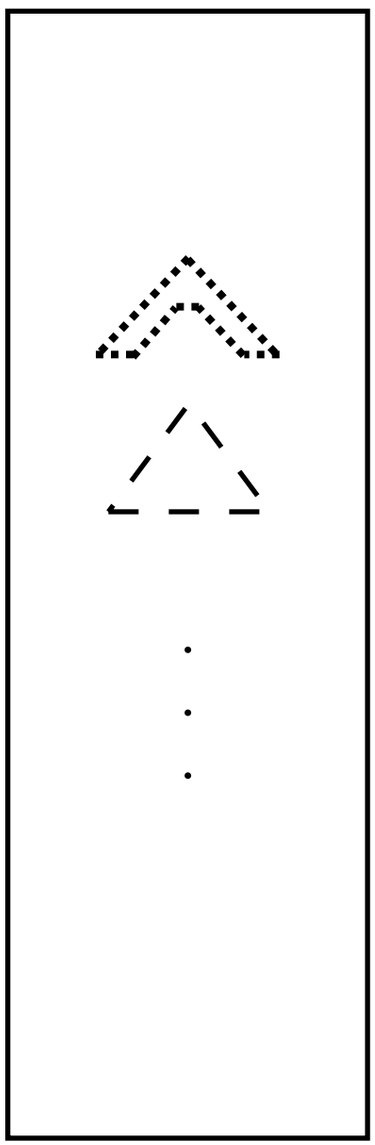

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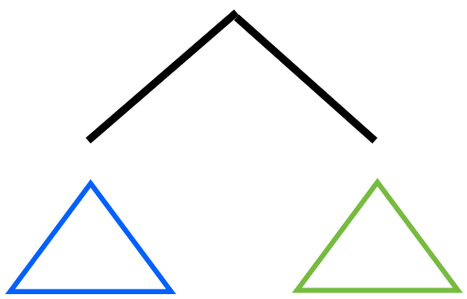

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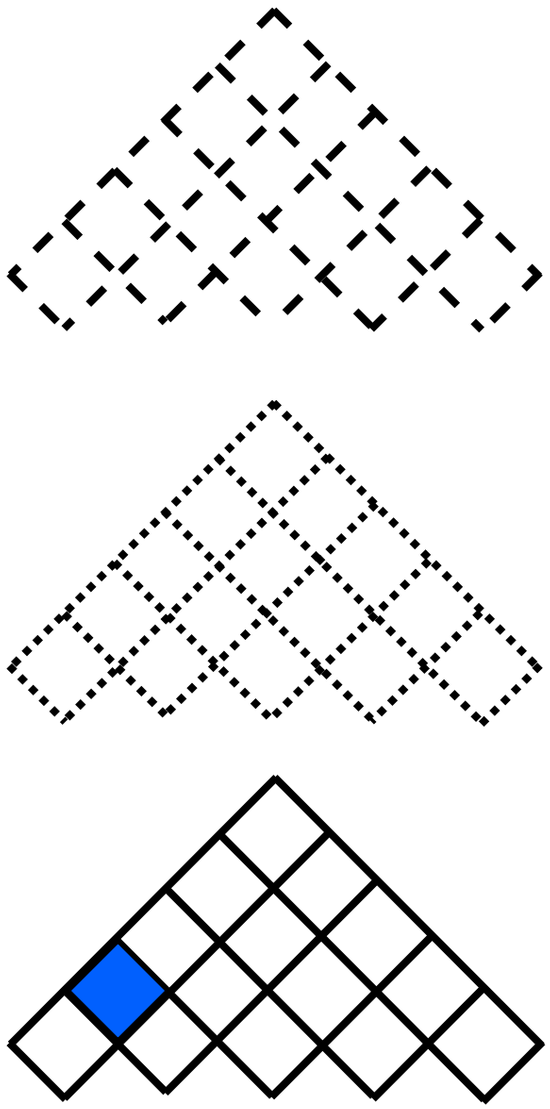

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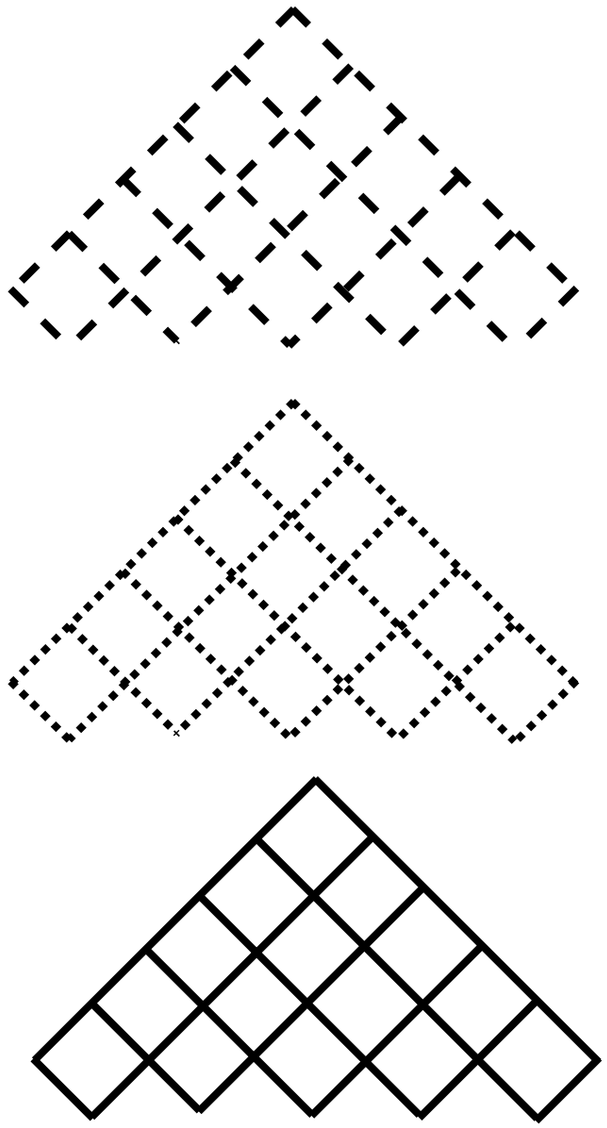

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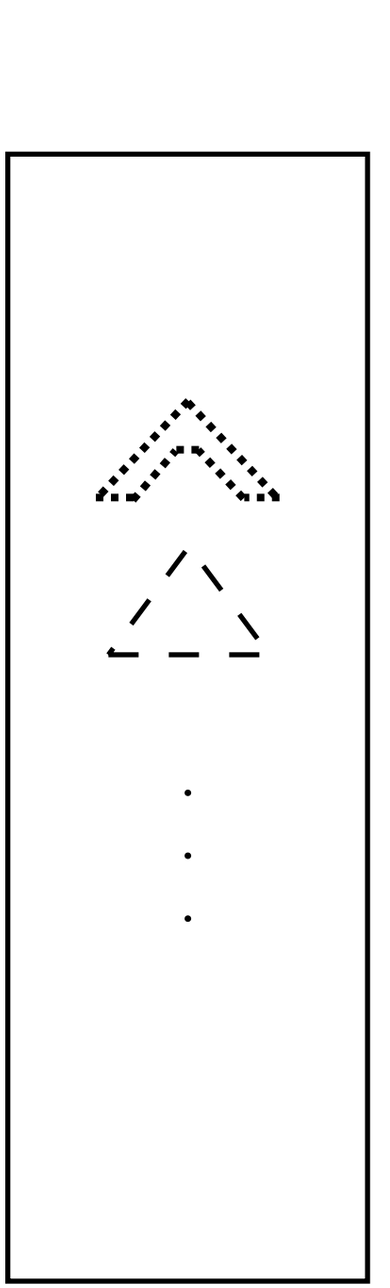

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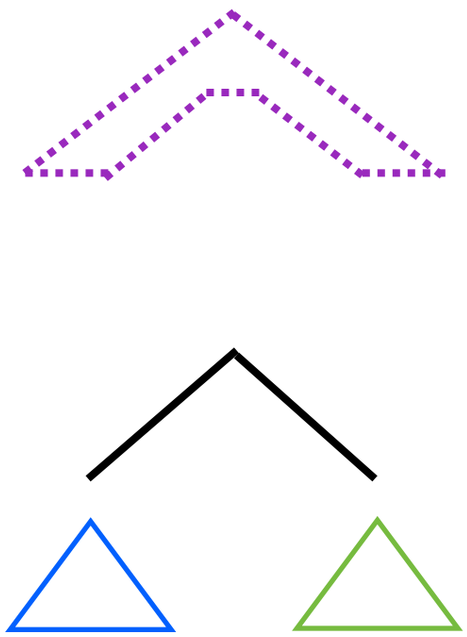

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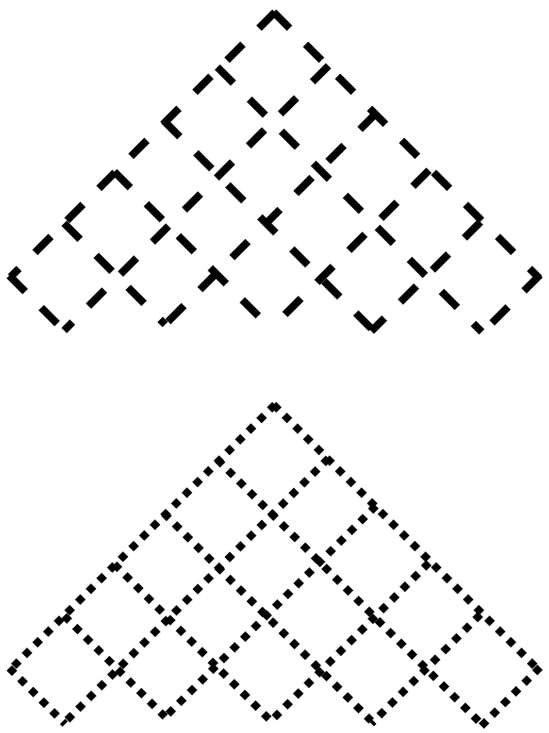

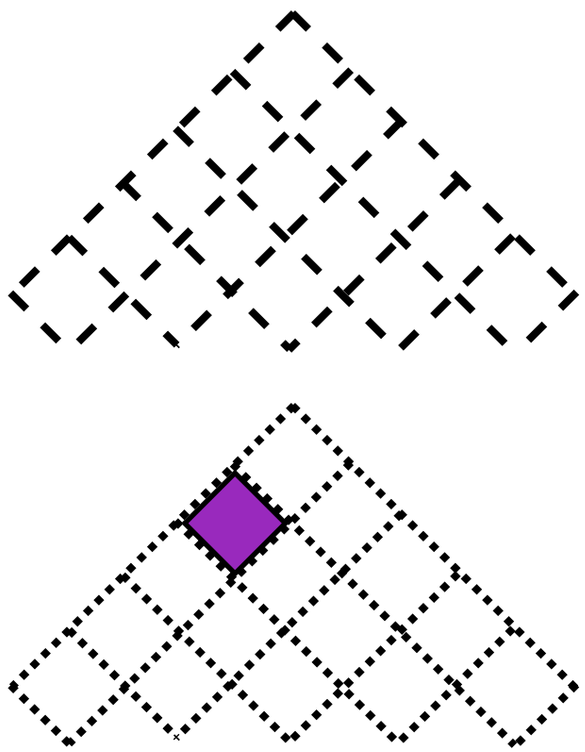

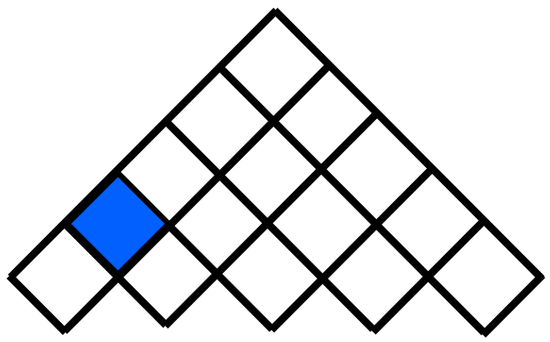

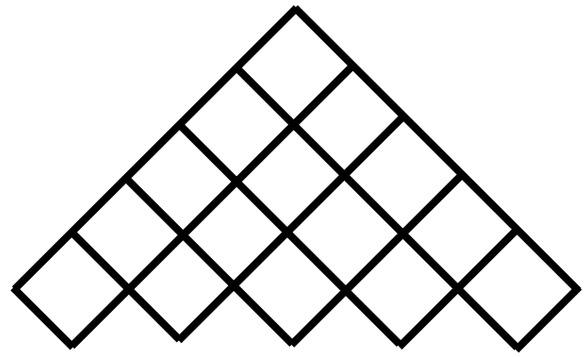

coarser

Charts

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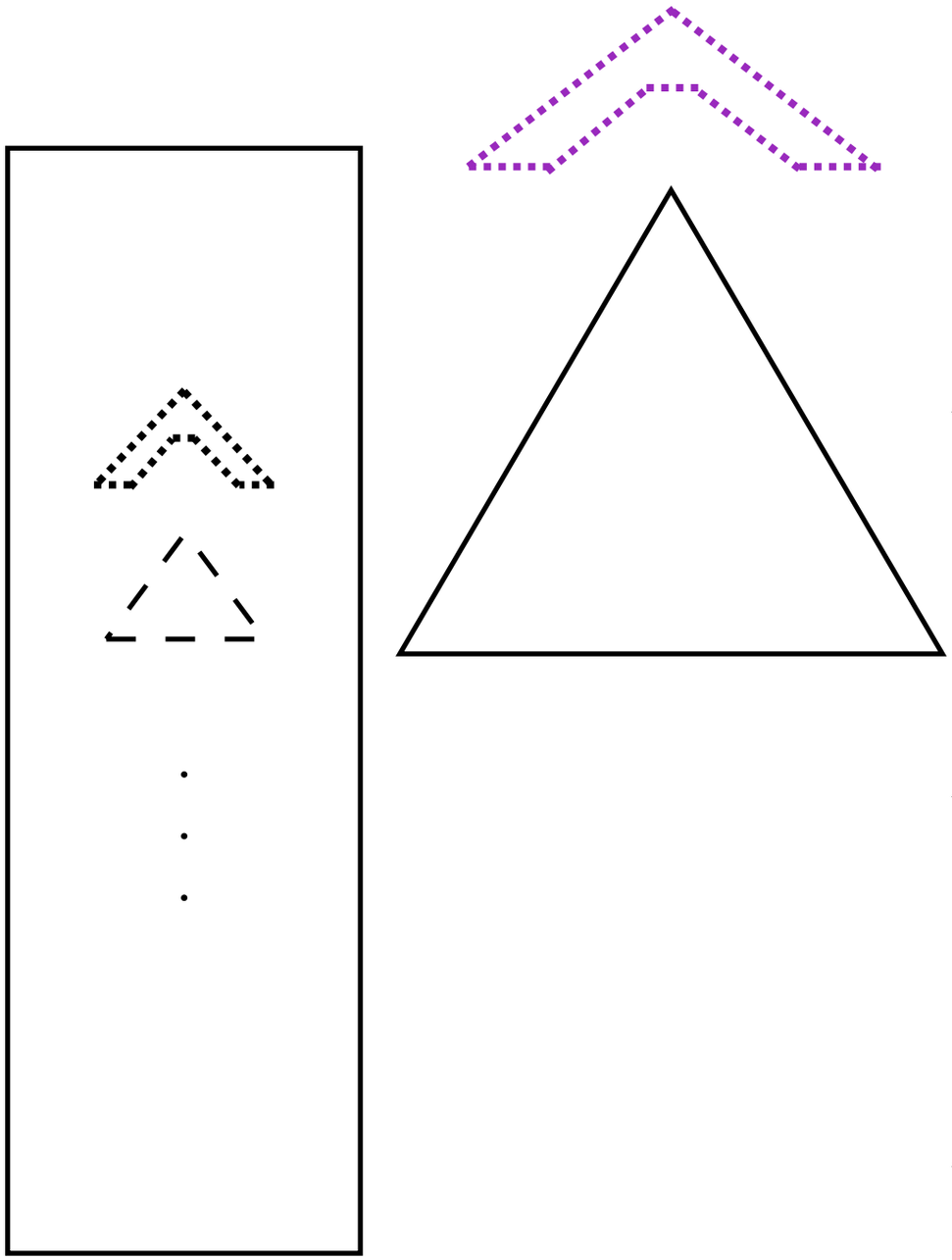

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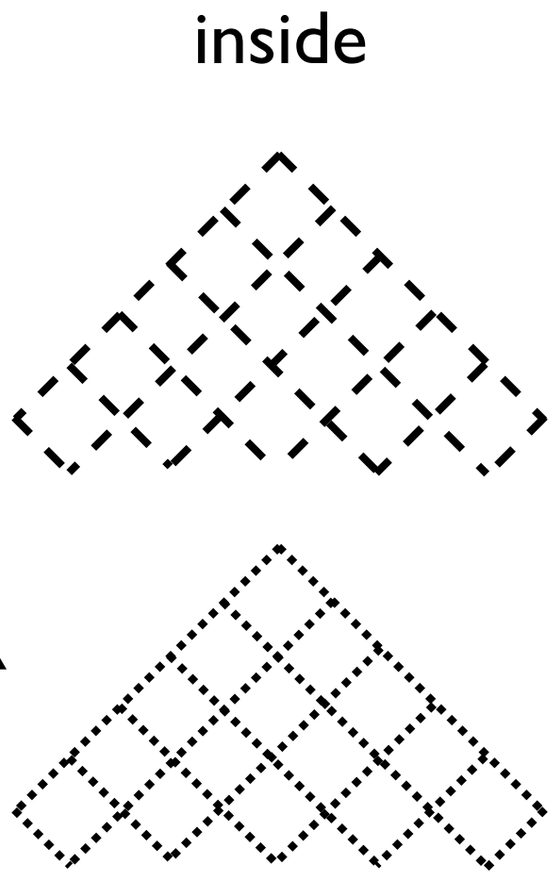

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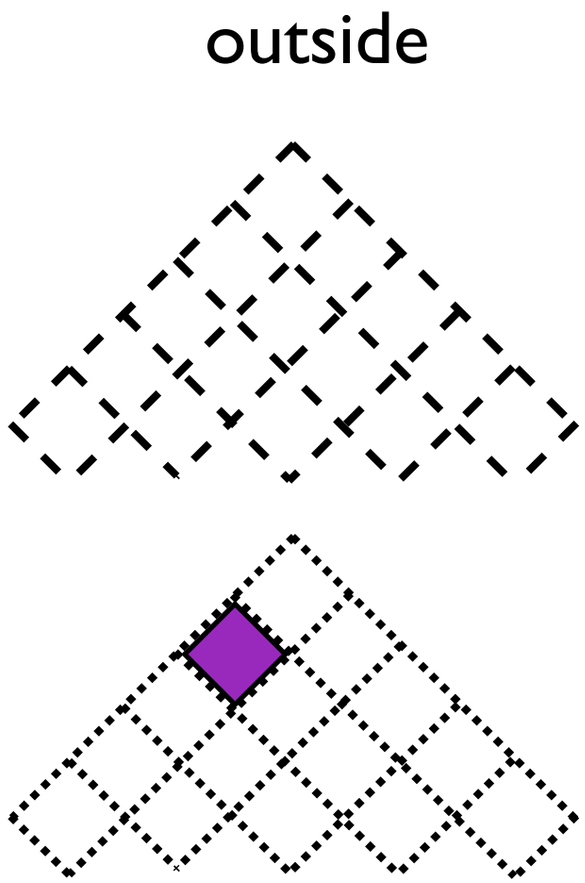

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Charts

coarser

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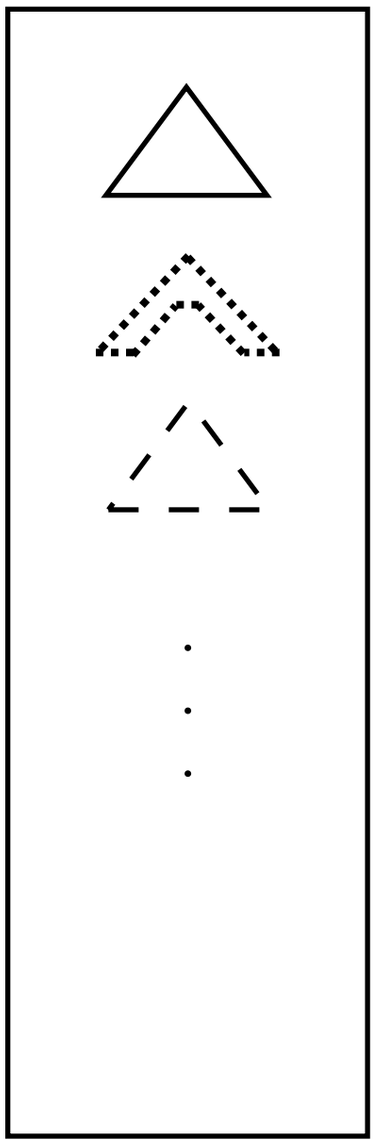

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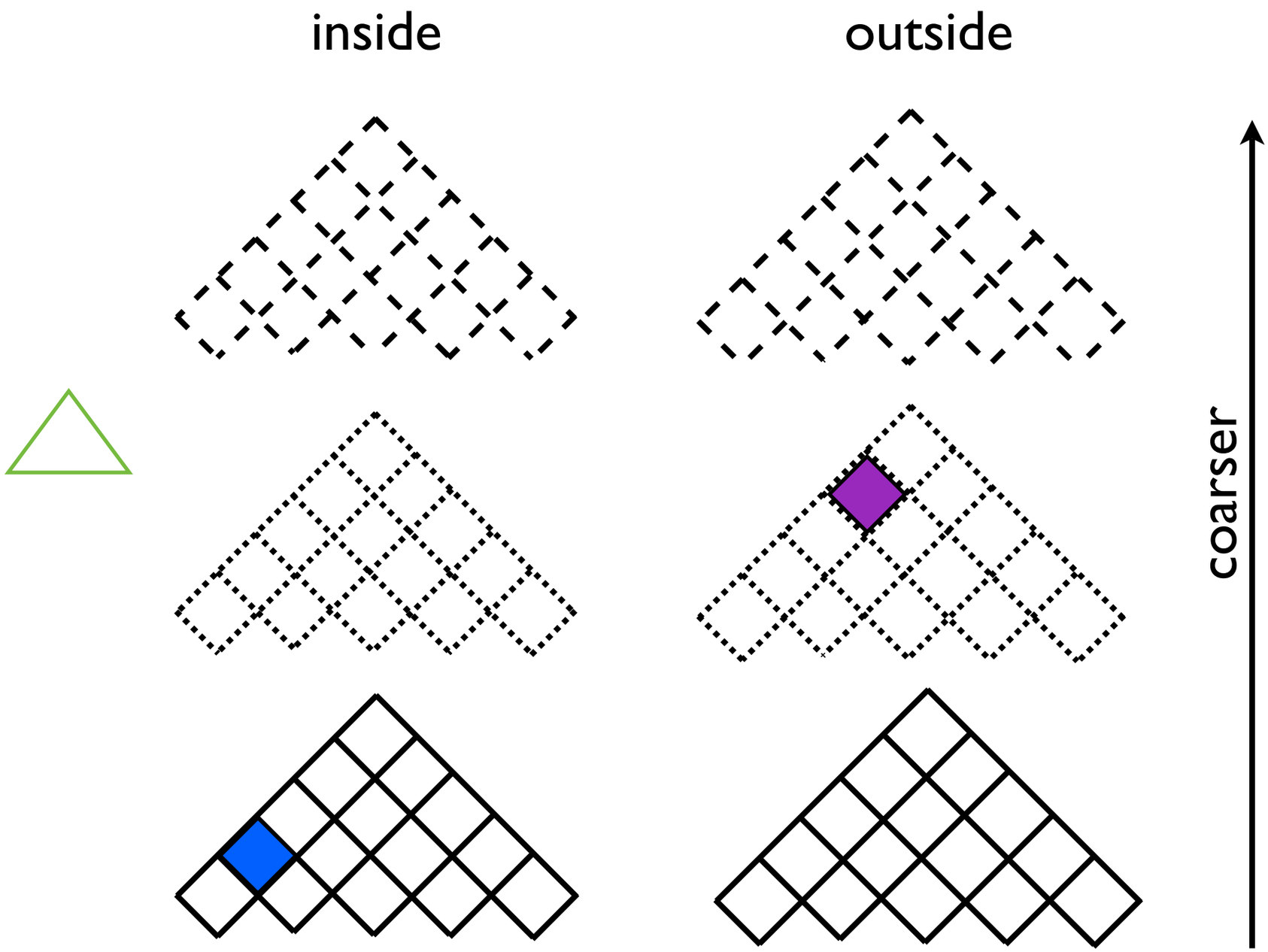

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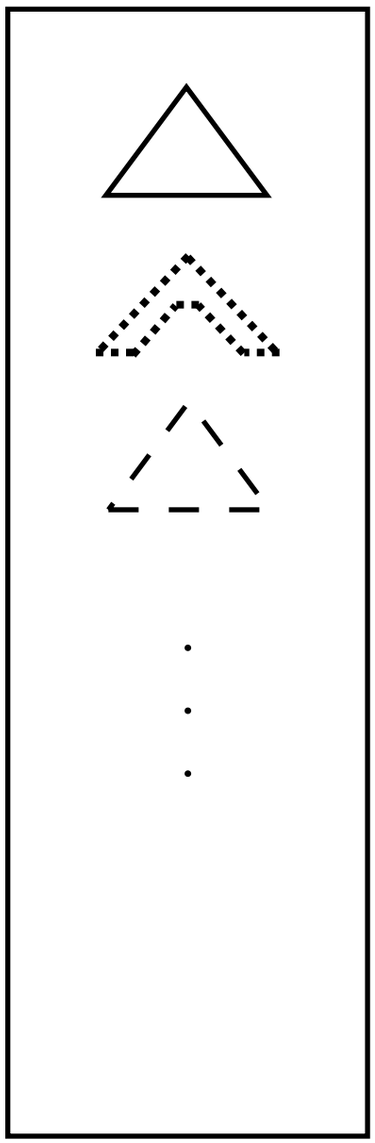

Agenda

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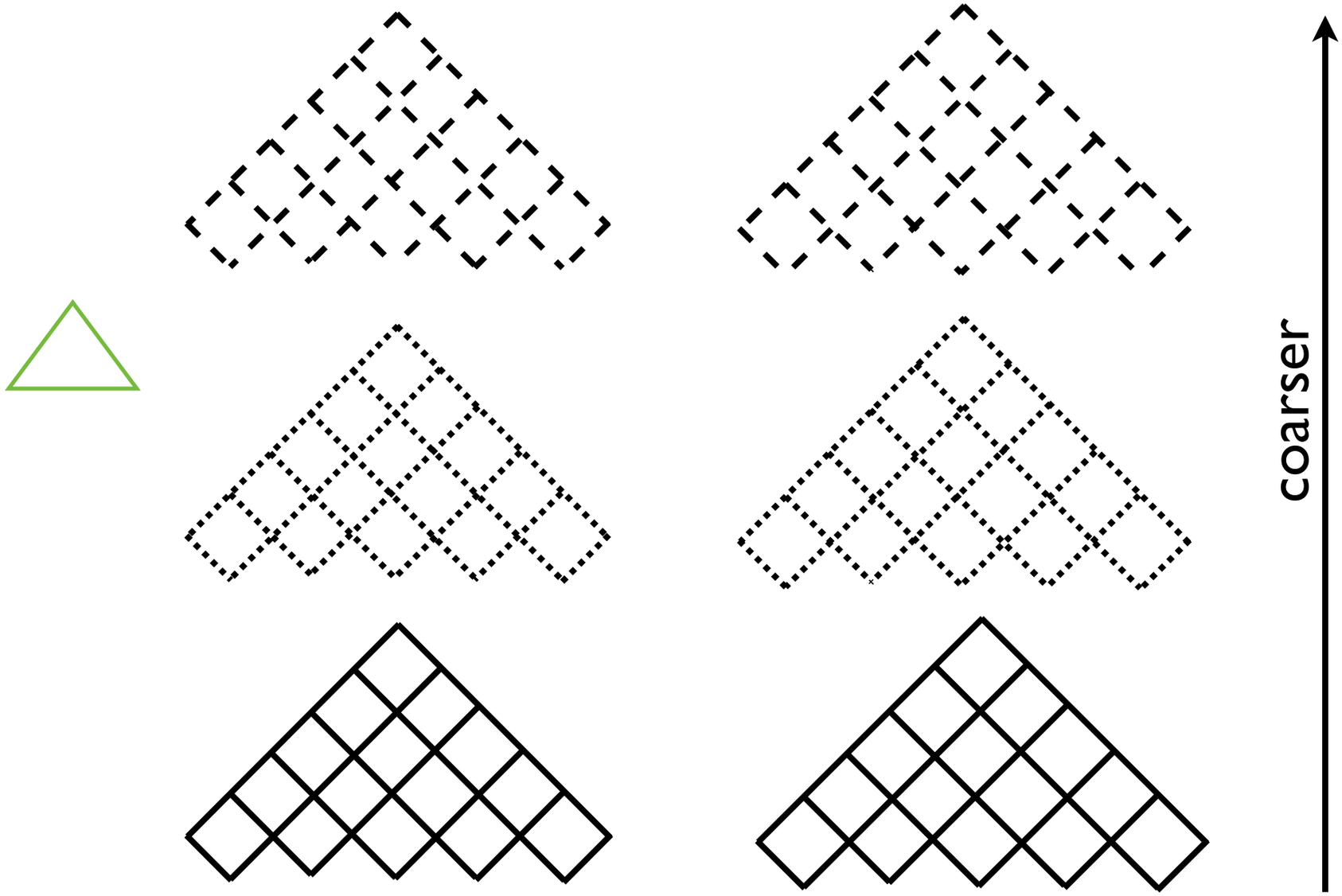

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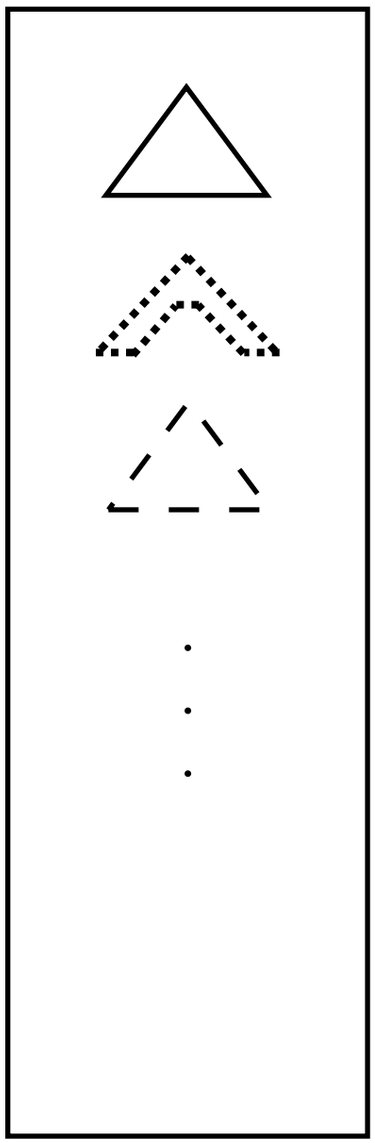

Agenda

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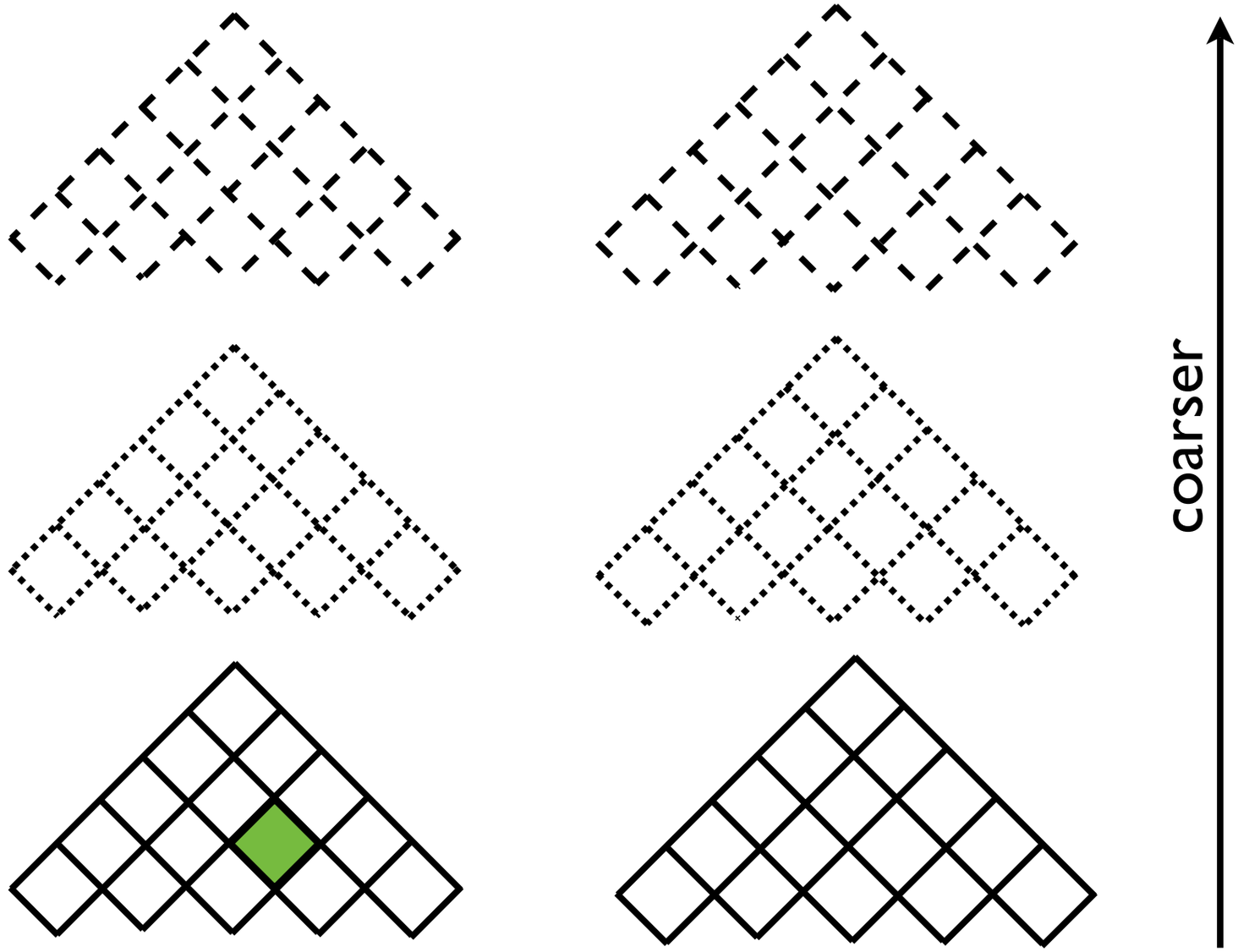
outside



Charts

Coarse-to-Fine

- Prune edges in fine grammar based on posteriors from coarse grammar

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$$\beta'(e) + \alpha'(e) \leq \text{threshold}$$

Agenda-Based CTF

- (Hierarchical) CTF can also be thought of as an instance of agenda-based parsing with

$$priority(e) = \begin{cases} \beta(e) & \beta'(e) + \alpha'(e) \leq \text{threshold} \\ \infty & \text{otherwise} \end{cases}$$

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- This reformulation makes architectures directly comparable

HA* vs. HCTF Qualitatively

HA*

HCTF

HA* vs. HCTF Qualitatively

HA*

- optimal

HCTF

- makes search errors

HA* vs. HCTF Qualitatively

HA*

- optimal
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HCTF

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HA* vs. HCTF Qualitatively

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- optimal
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HCTF

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- uses coarse grammars to prune search
- speed determined by threshold

HA* vs. HCTF Qualitatively

HA*	HCTF
optimal	makes search errors
uses coarse grammars to prioritize search	uses coarse grammars to prune search
speed determined by tightness of heuristic	speed determined by threshold
min over rules	average over rules

Experimental Setup #1

- Use the state-split grammars of Petrov *et al.* 2006
- Train on WSJ Sections 2-21, and use 6 split iterations, which creates 7 grammars

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NP

0-split

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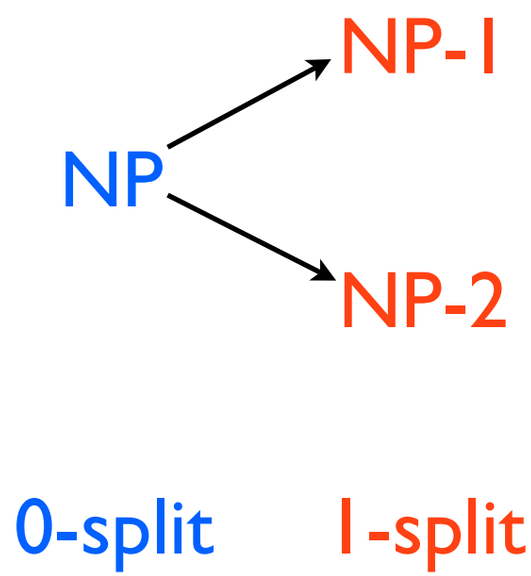

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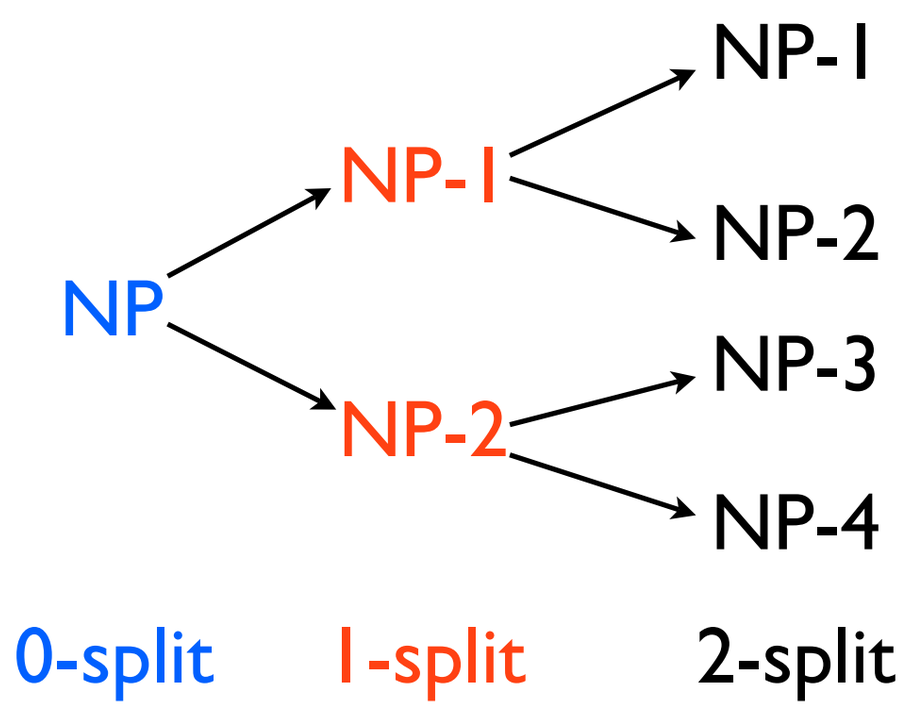

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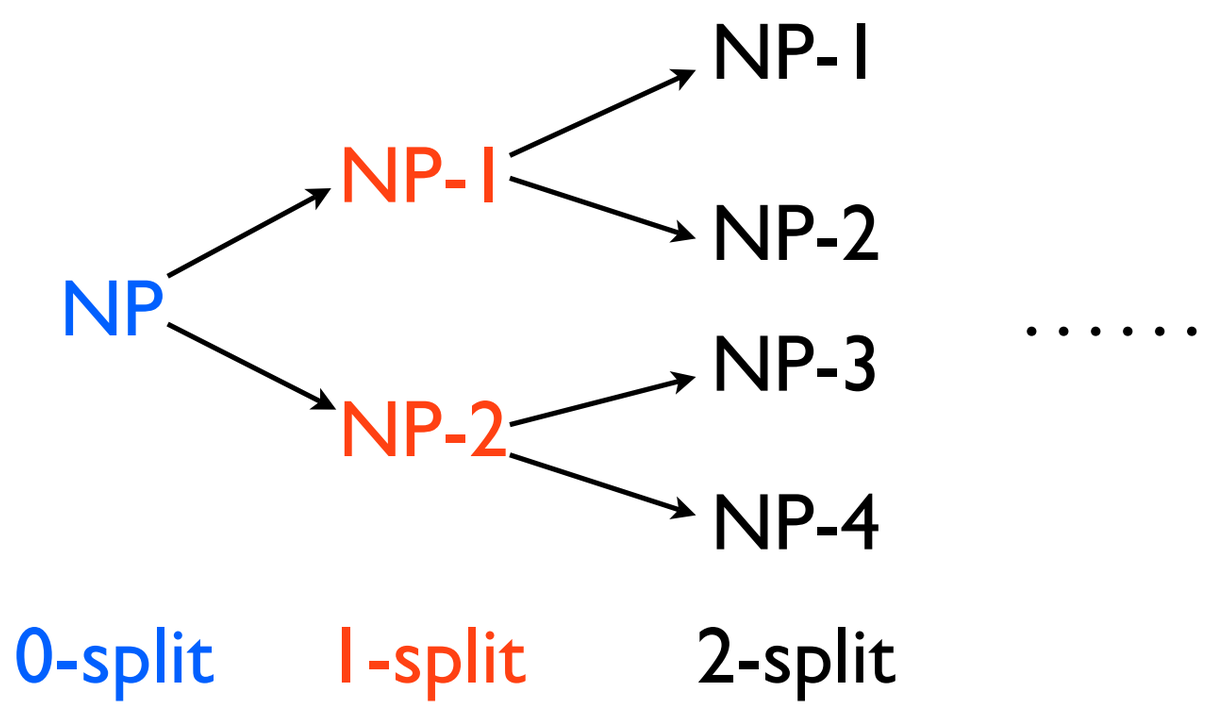
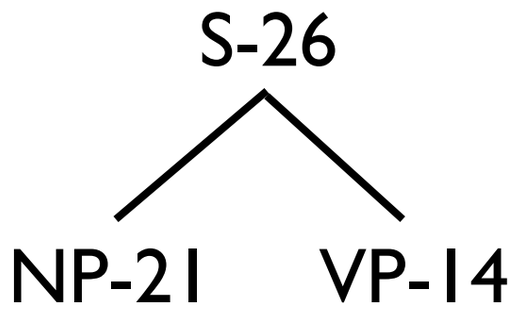
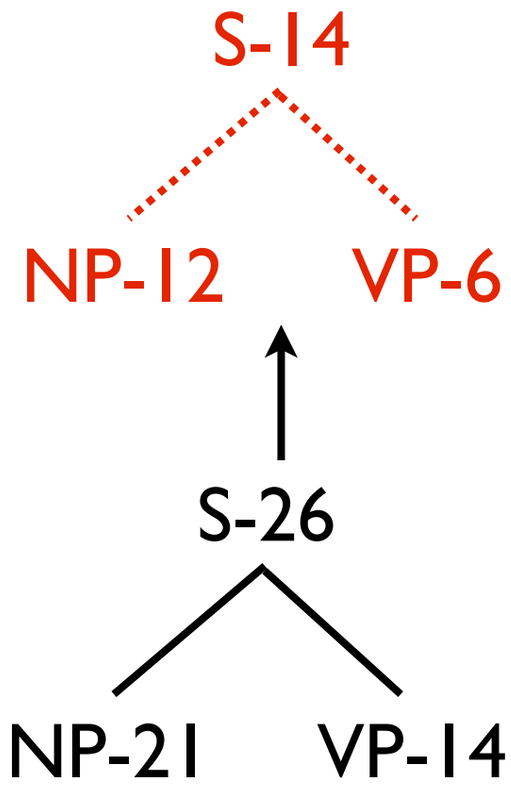


State-Split Projections



6-split

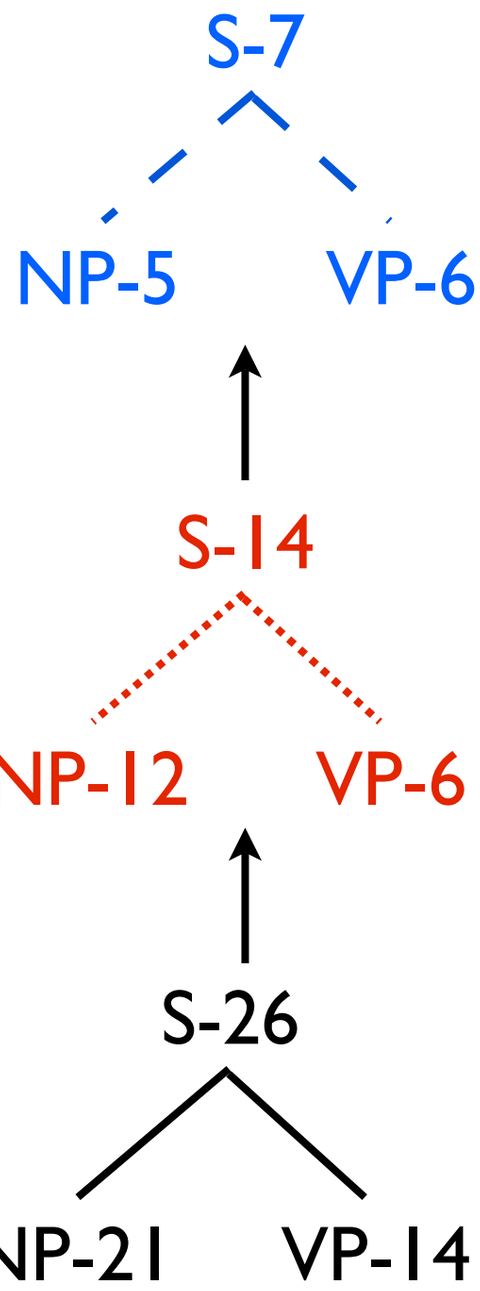
State-Split Projections



5-split

6-split

State-Split Projections

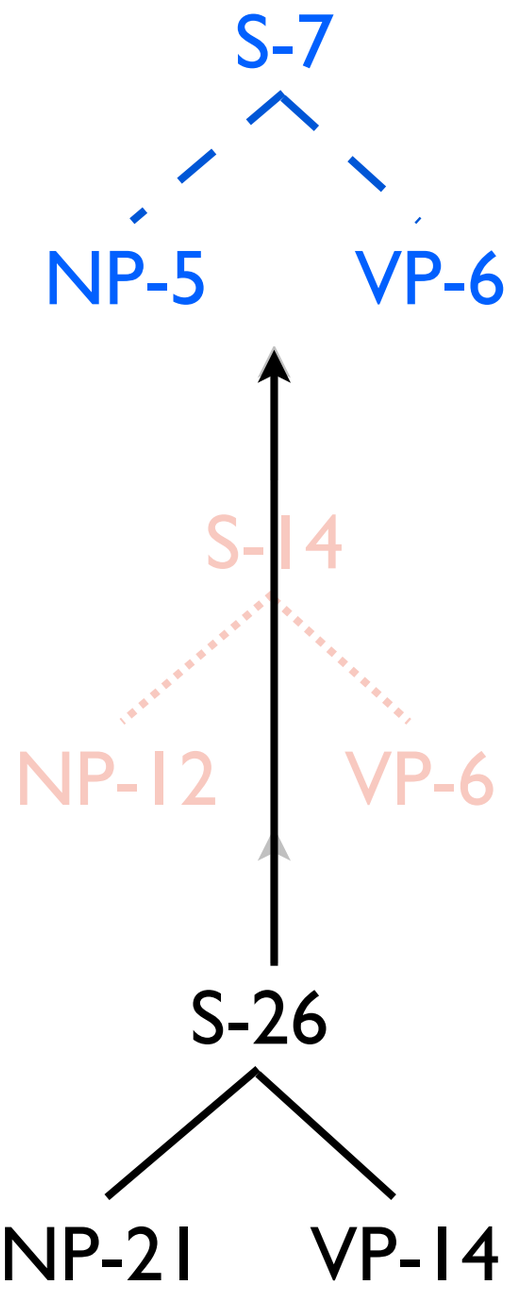


4-split

5-split

6-split

State-Split Projections



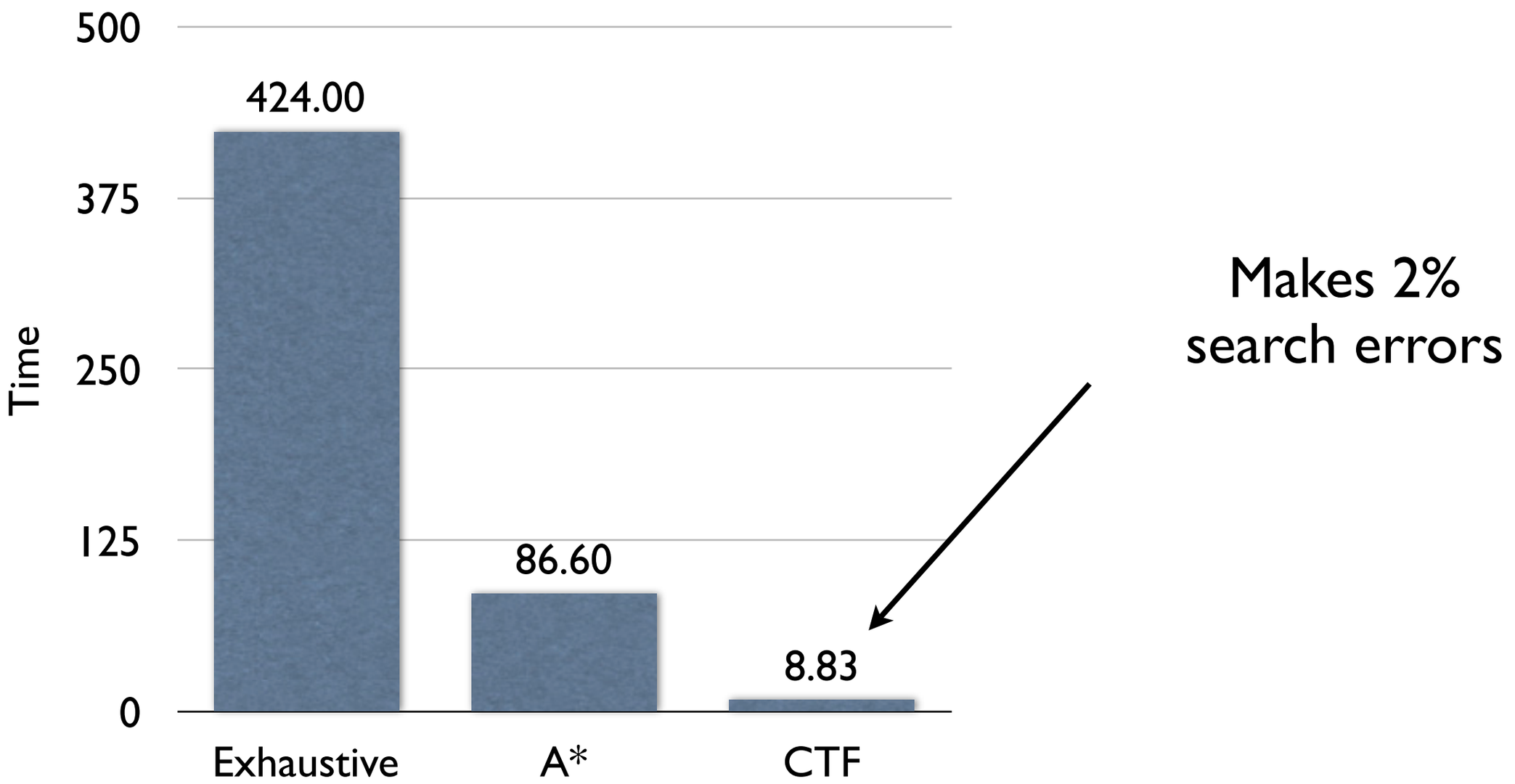
4-split

5-split

6-split

One-Level CTF vs. A*

- Only one coarse grammar (the 3-split)
- CTF is faster than A*, but makes search errors



Hierarchies

- How do HCTF and HA* scale with size of hierarchy?

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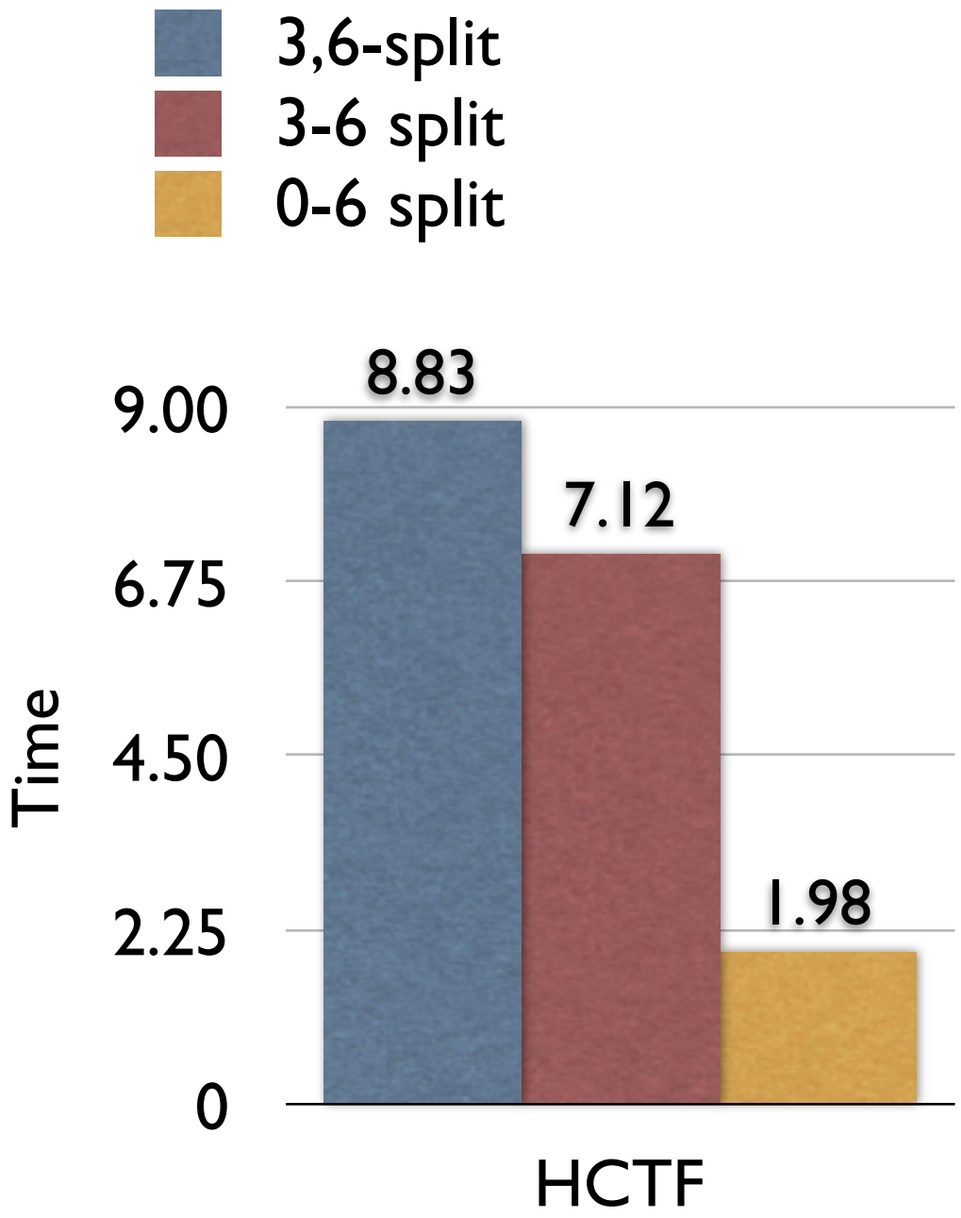
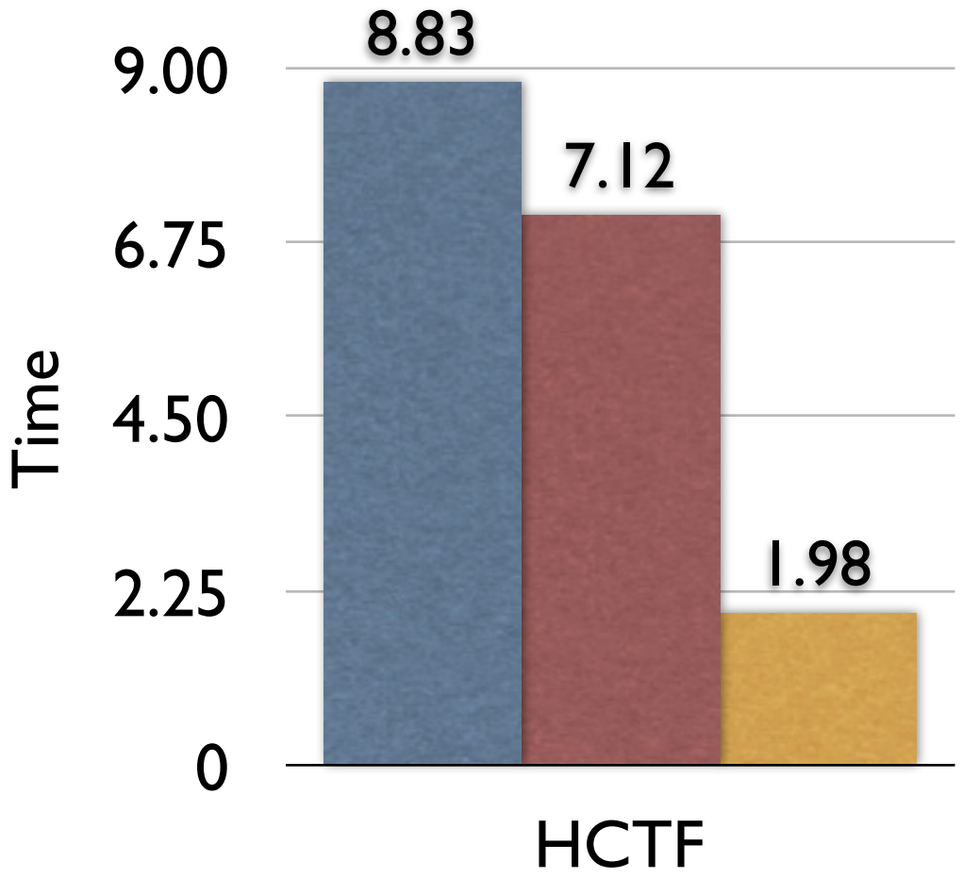
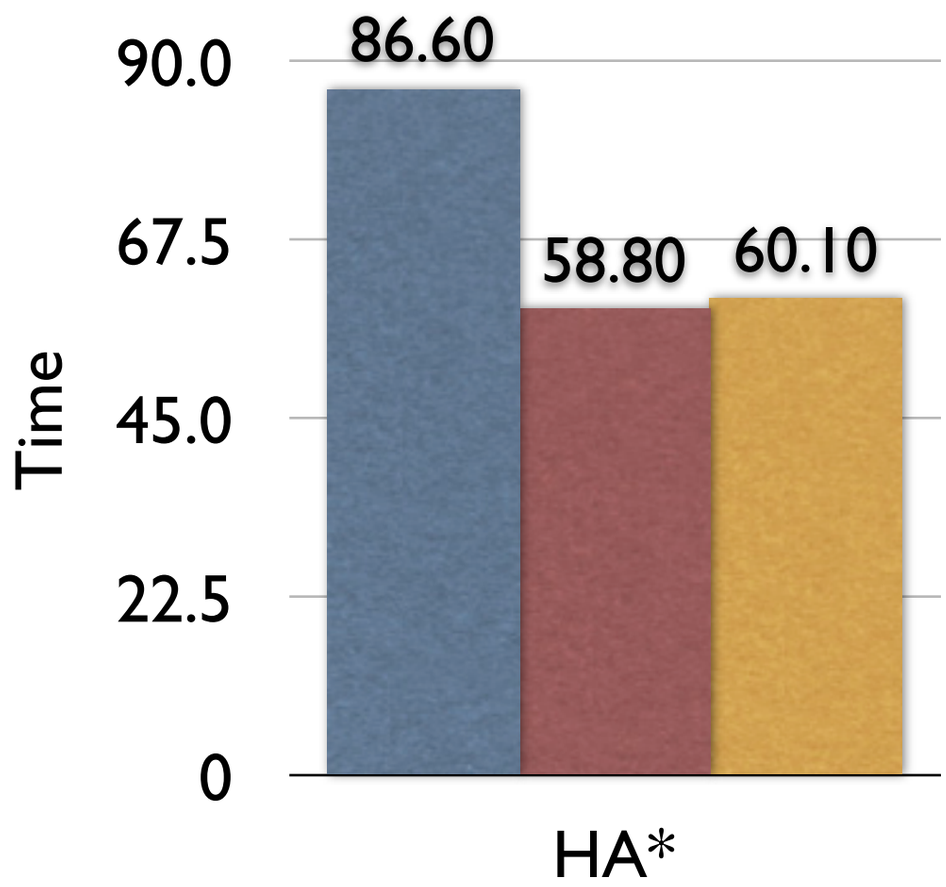


Hierarchies

- How do HCTF and HA* scale with size of hierarchy?

3,6-split
3-6 split
0-6 split



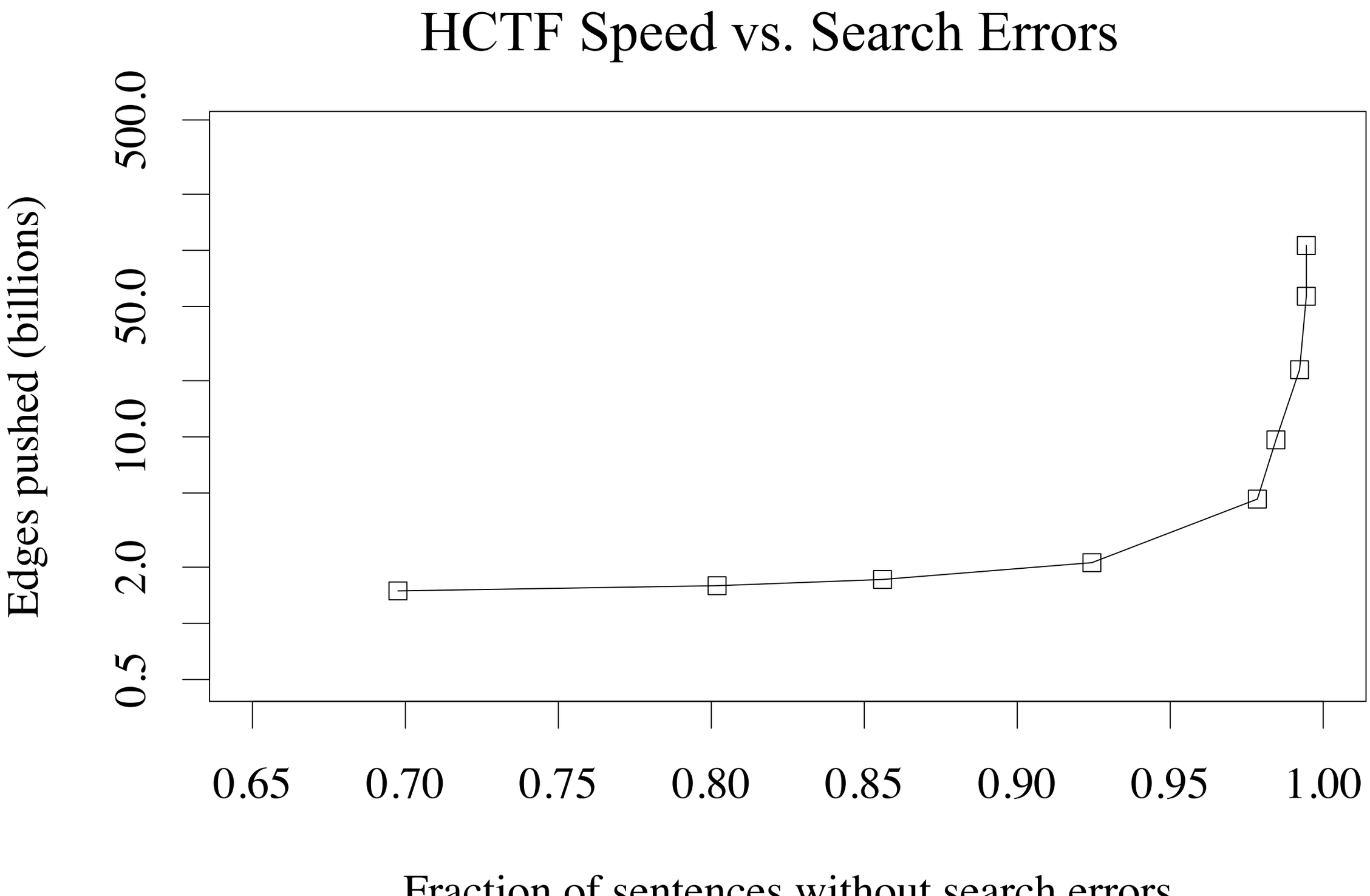


Why A*?

- CTF is faster, and extends to hierarchies nicely, so why A*?

1. If you really don't want to make search errors

Cost of Optimality: State-Split Grammars



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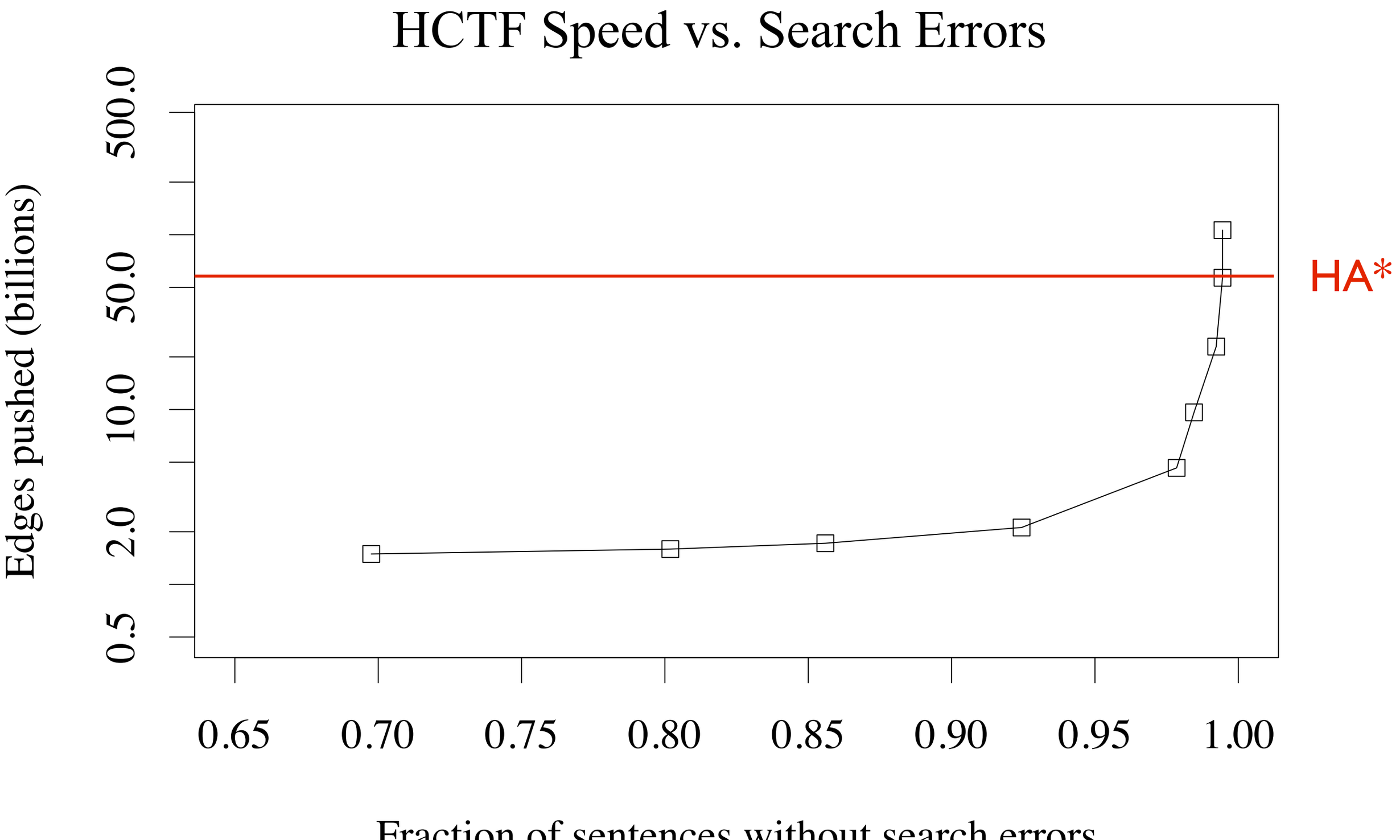

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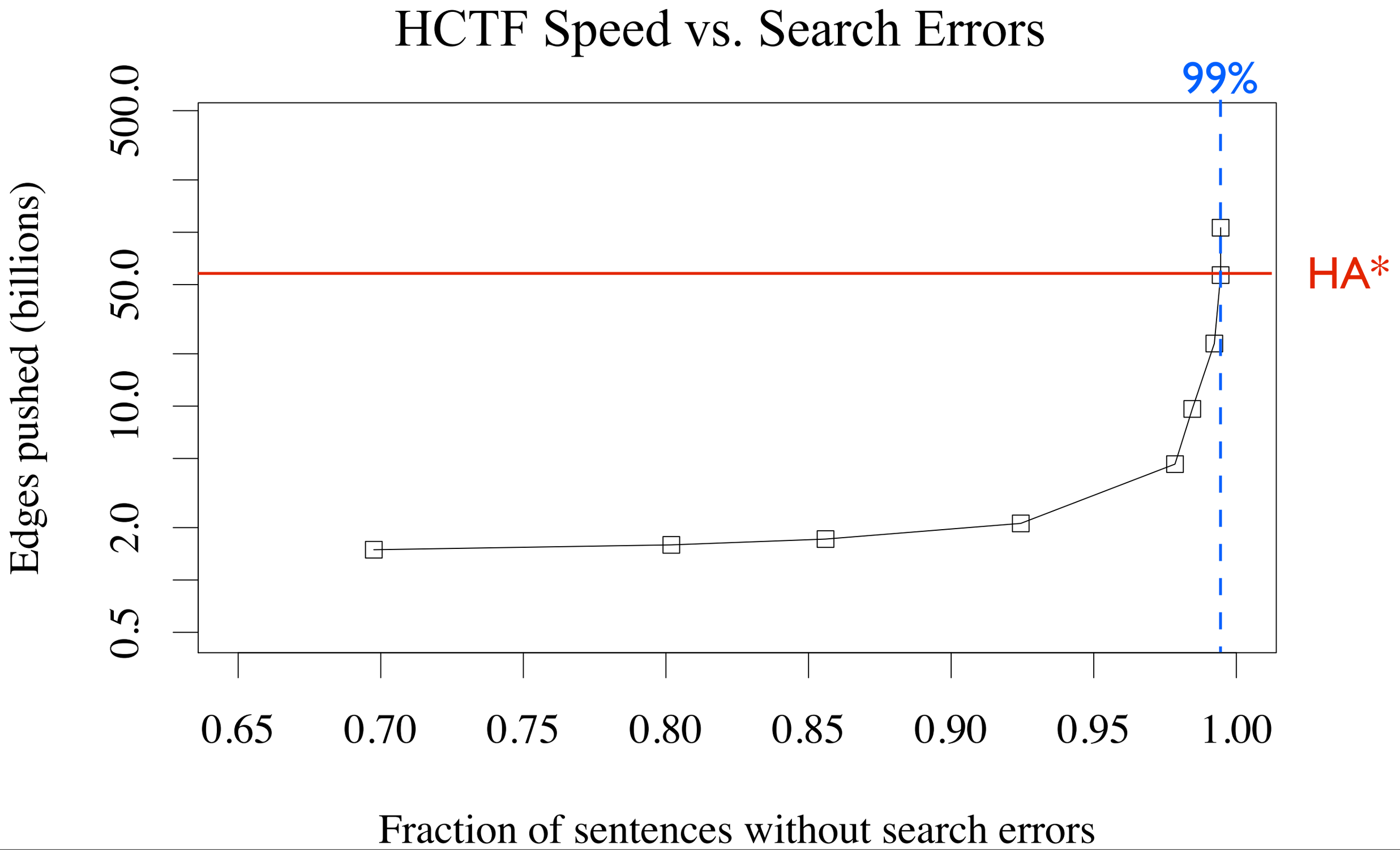

Why A*?

- CTF is faster, and extends to hierarchies nicely, so why A*?

1. If you really don't want to make search errors

2. For some problems, we can find very efficient, tight heuristics

- In this case, A* is very fast

Experimental Setup #2

- We use the factored lexicalized grammar of Klein and Manning (2003)
- They construct a lexicalized grammar as the cross-product of a dependency grammar and PCFG

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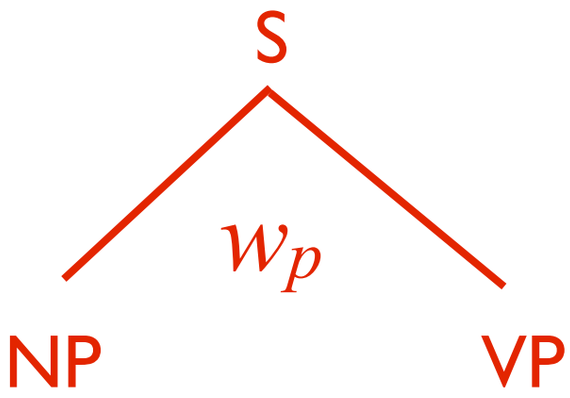

PCFG

Experimental Setup #2

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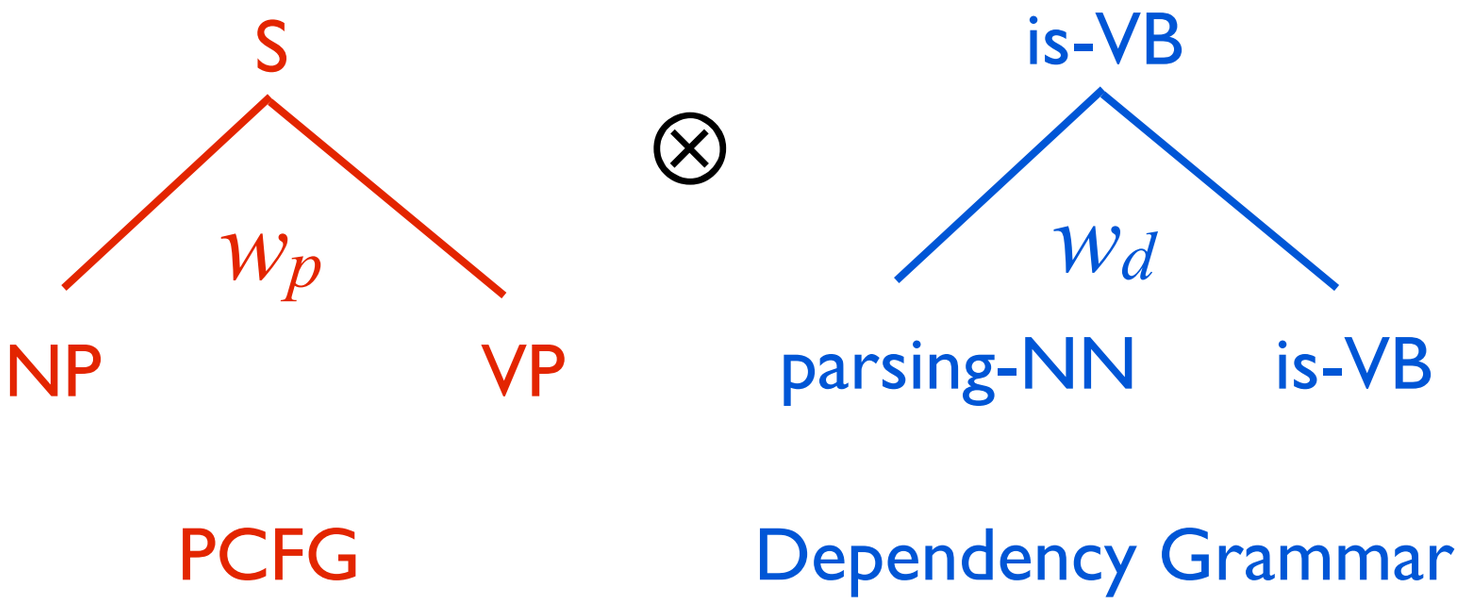

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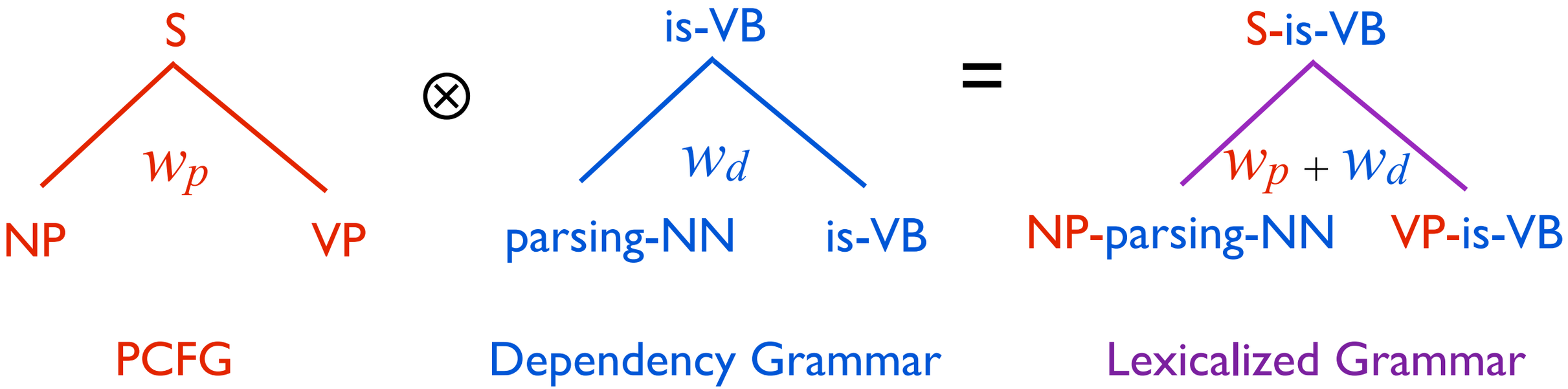
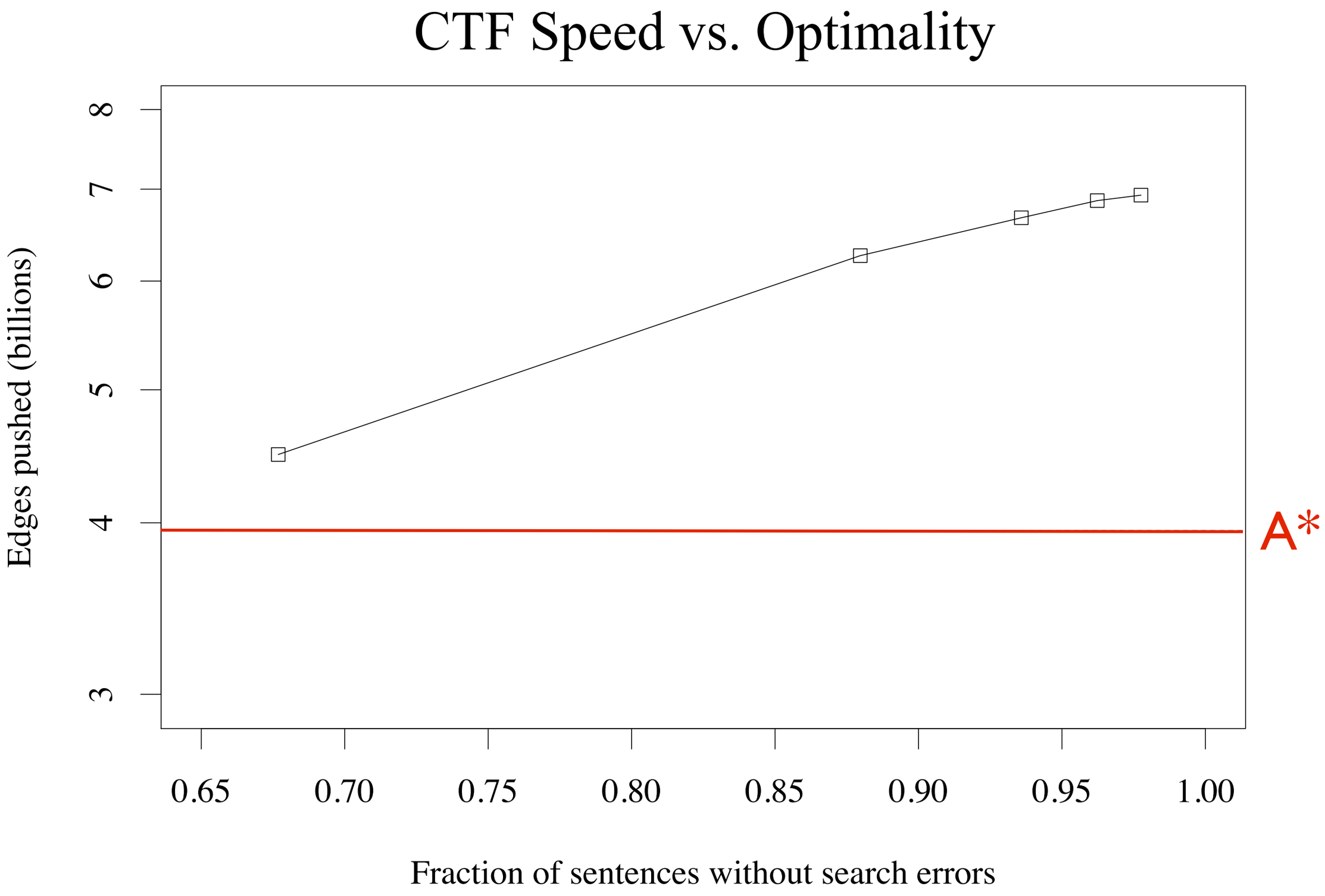


Cost of Optimality: Lexicalized Grammar



Conclusions

- Coarse-to-Fine is much faster for reasonable number of search errors
- Hierarchical Coarse-to-Fine effectively exploits multilevel hierarchies, Hierarchical A* does not
- Hierarchical A* is the right choice if
  - optimality is desired
  - heuristics are very tight

Thank you