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)

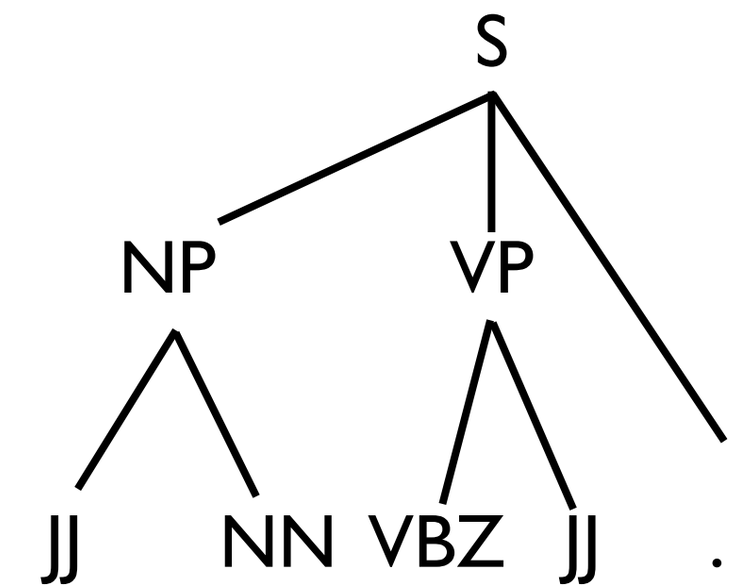
- Multi-level or Hierarchical Coarse-to-Fine works even better (Charniak and Johnson 2005, Petrov and Klein 2007)

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

Hierarchical Setting

fast parsing is fun .

Hierarchical Setting



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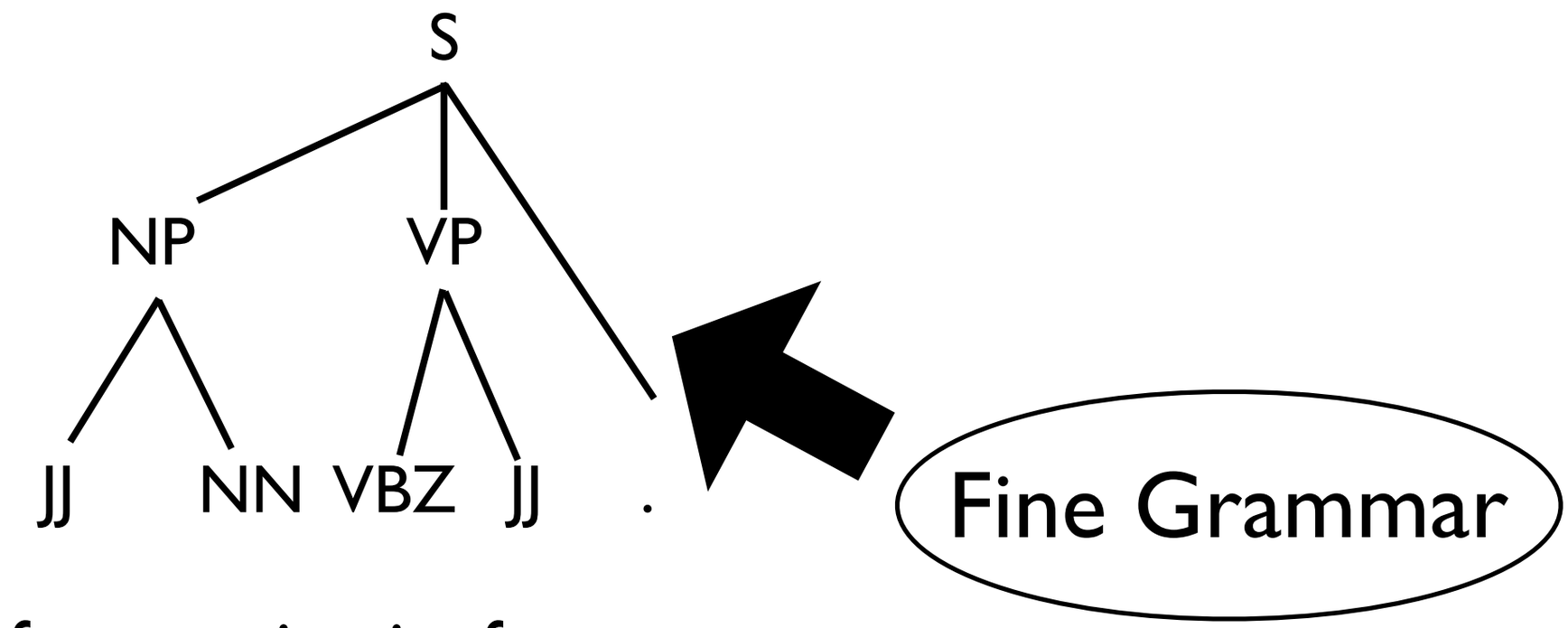

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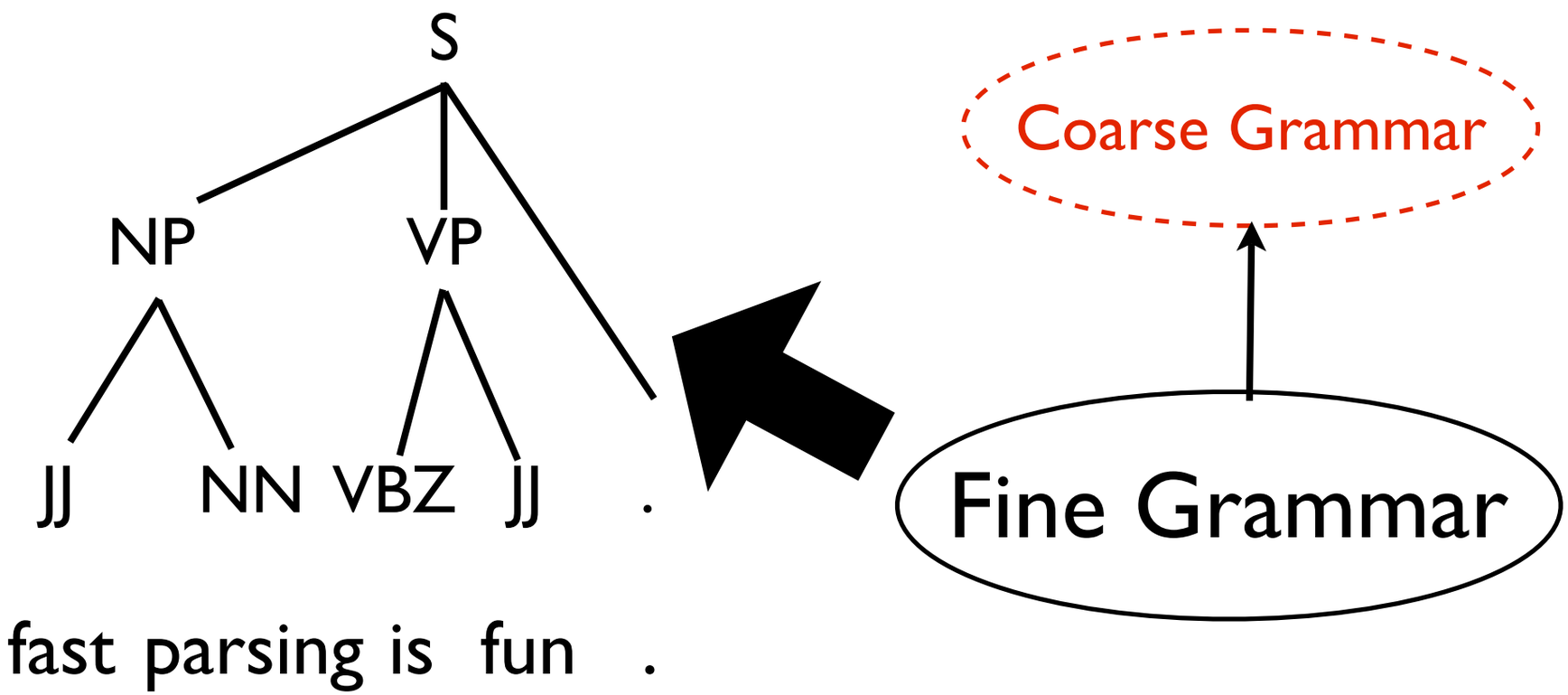

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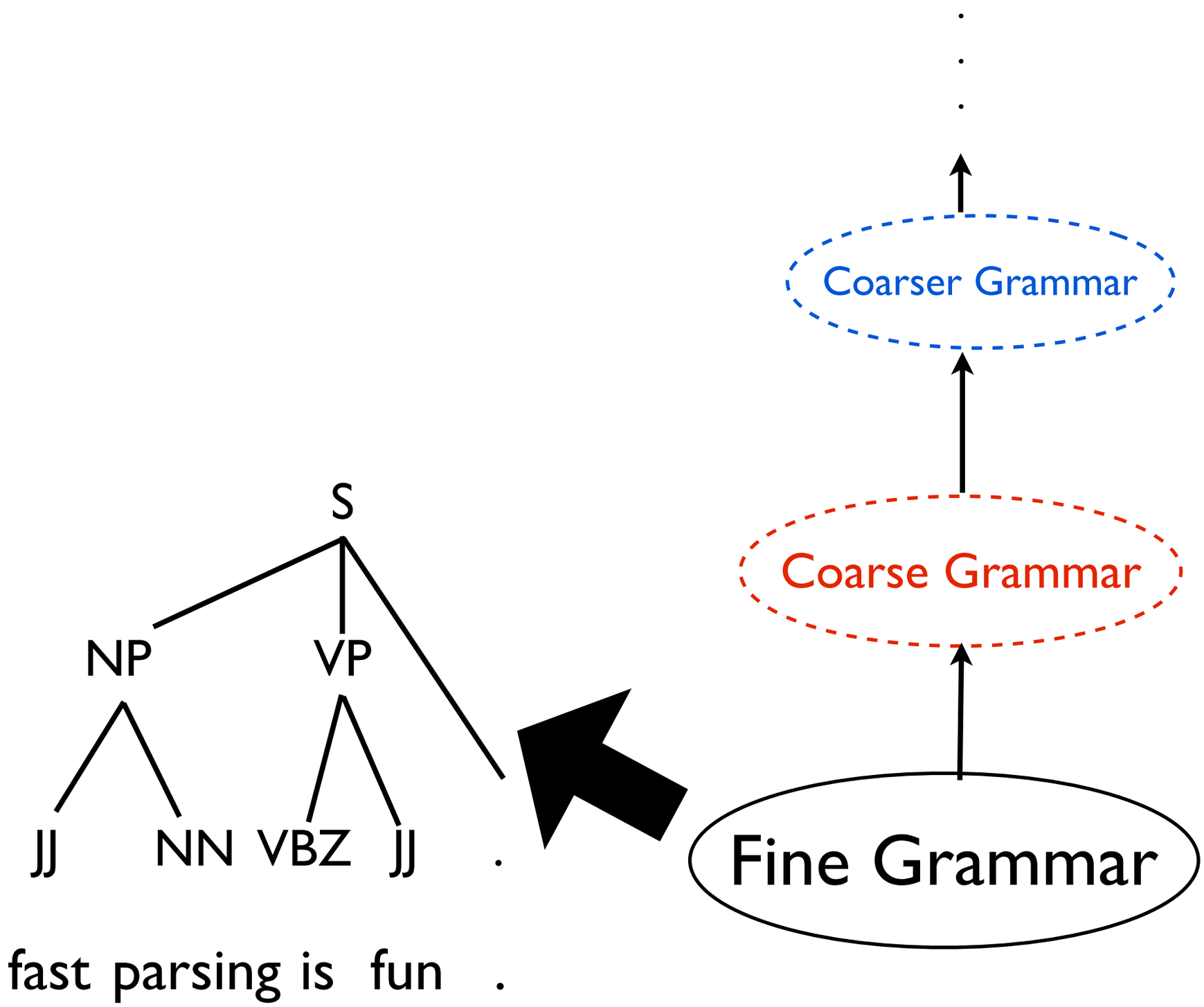

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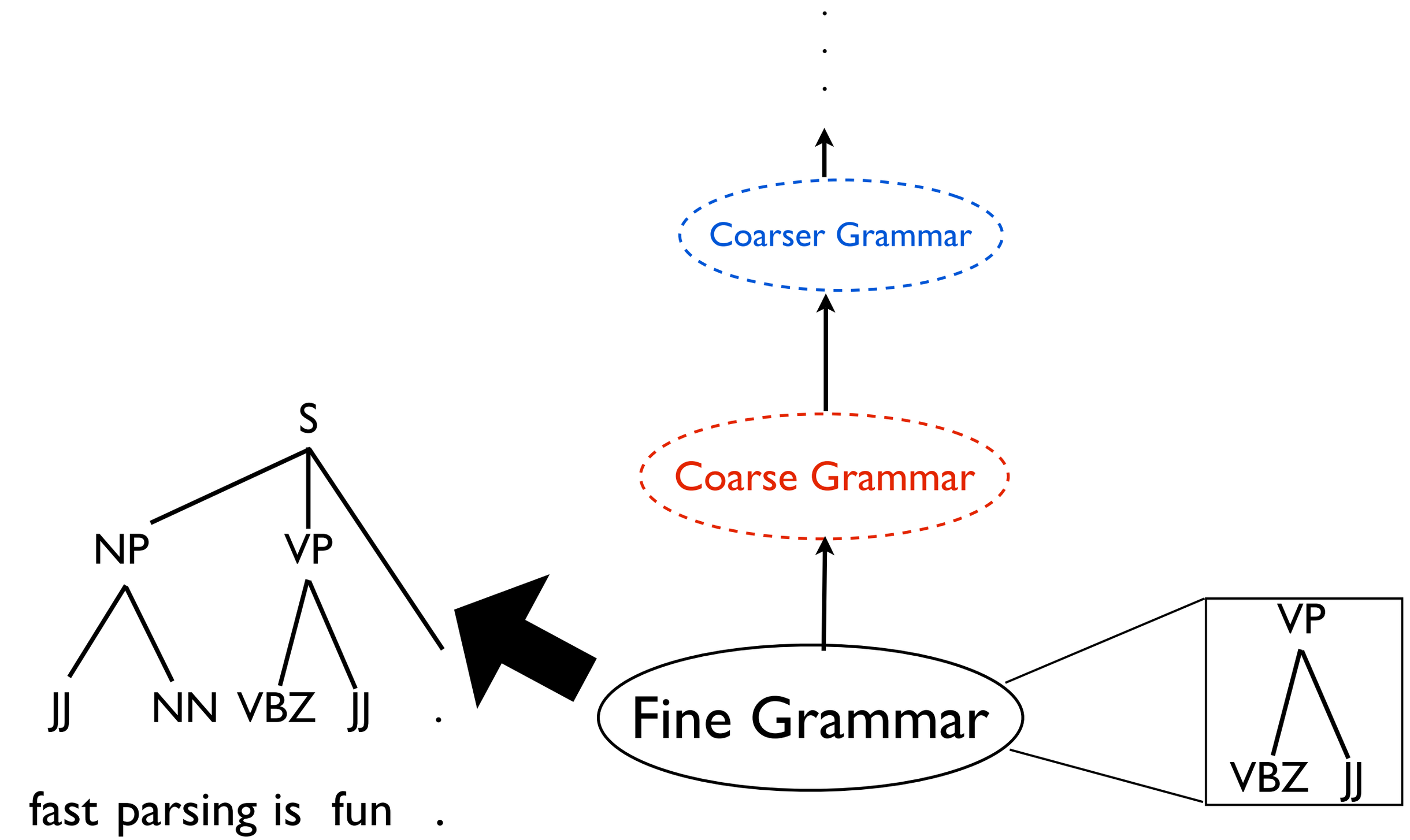

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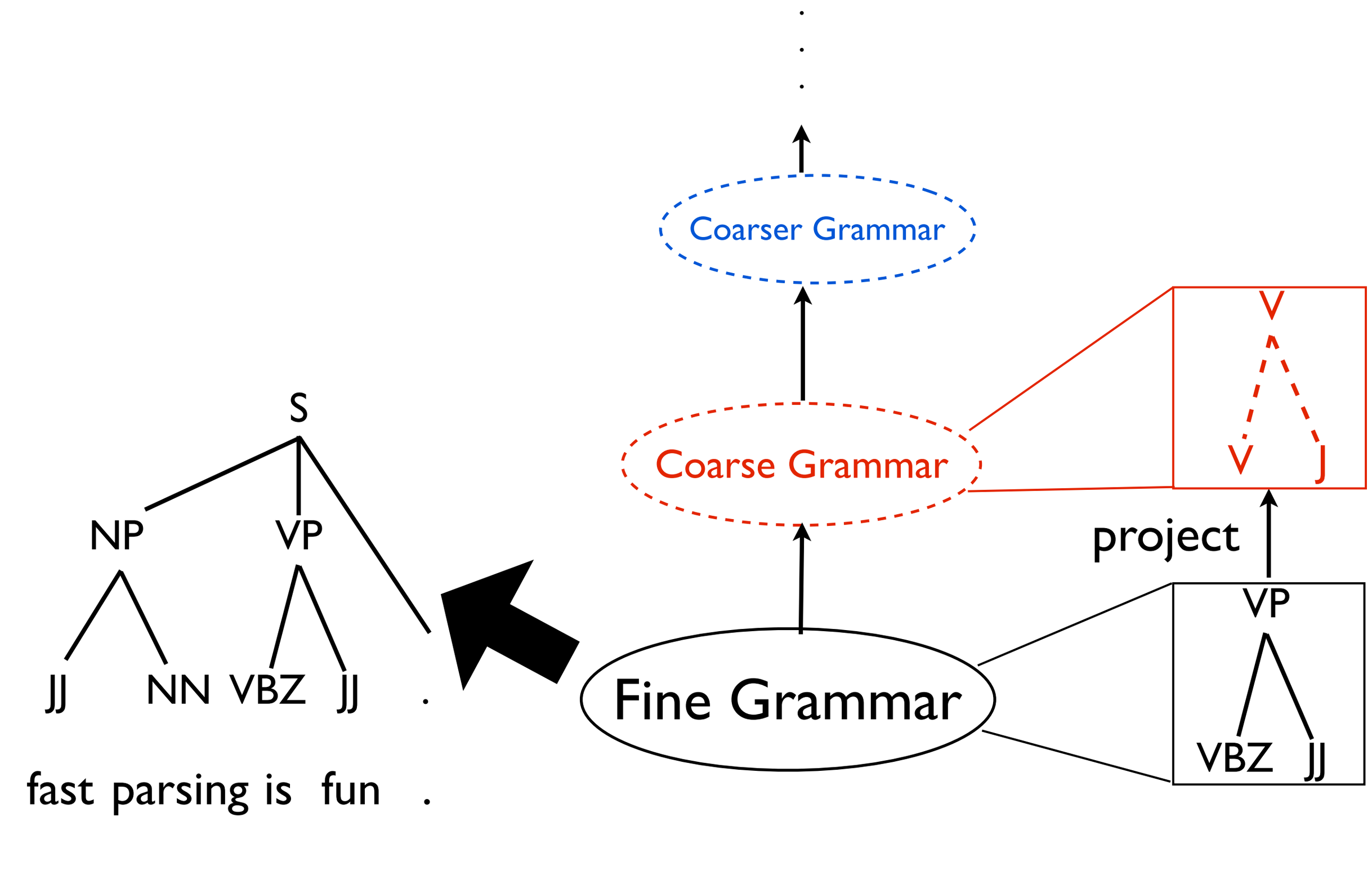
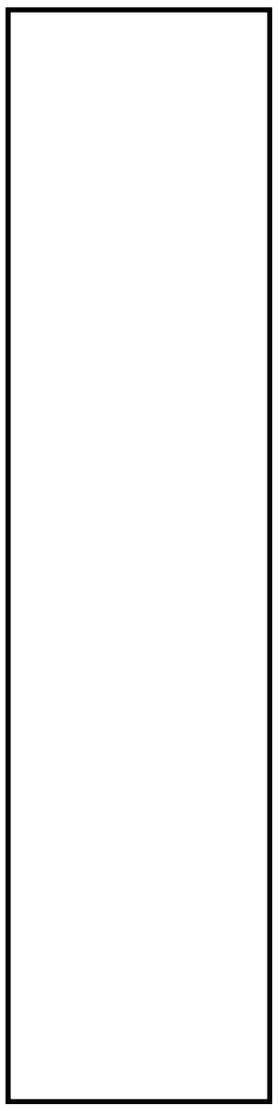


Agenda-Based Search



Agenda

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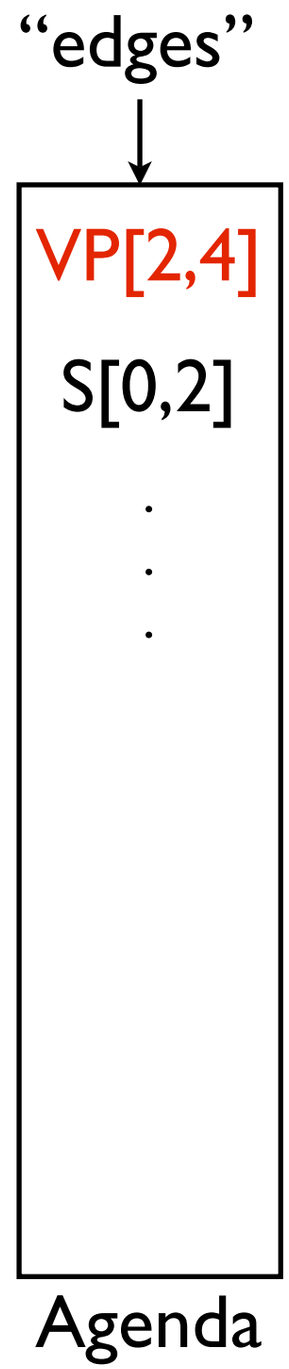

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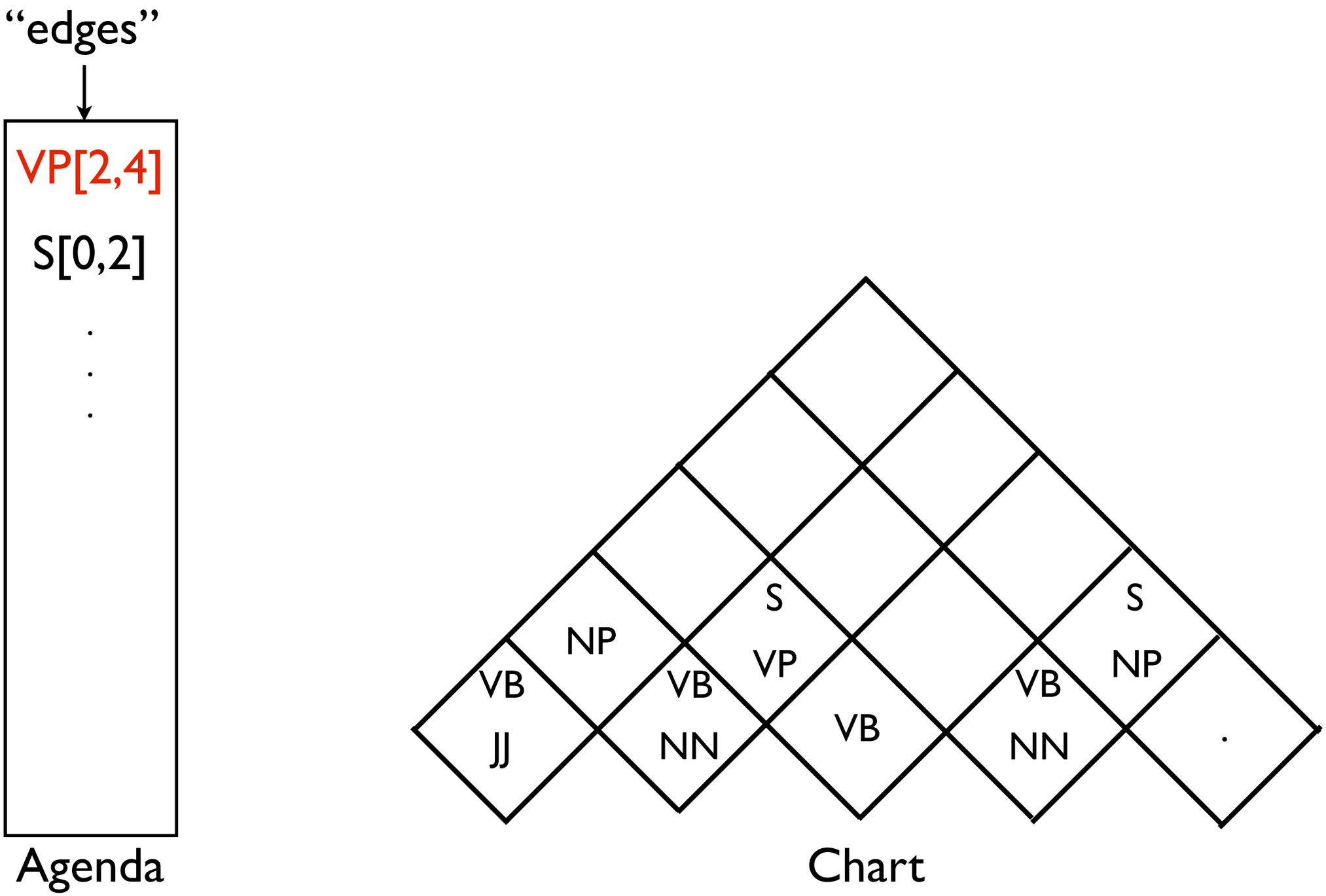

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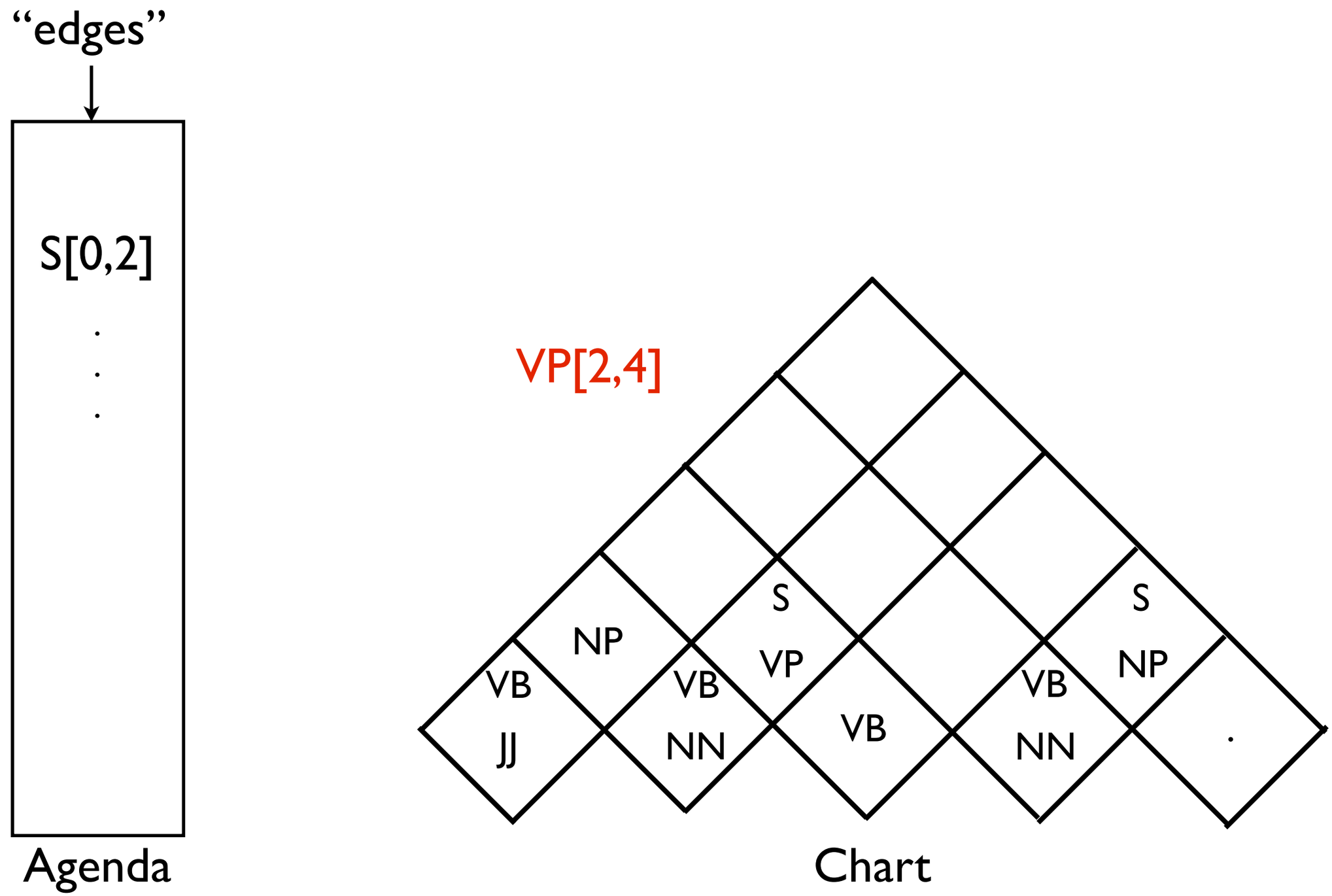

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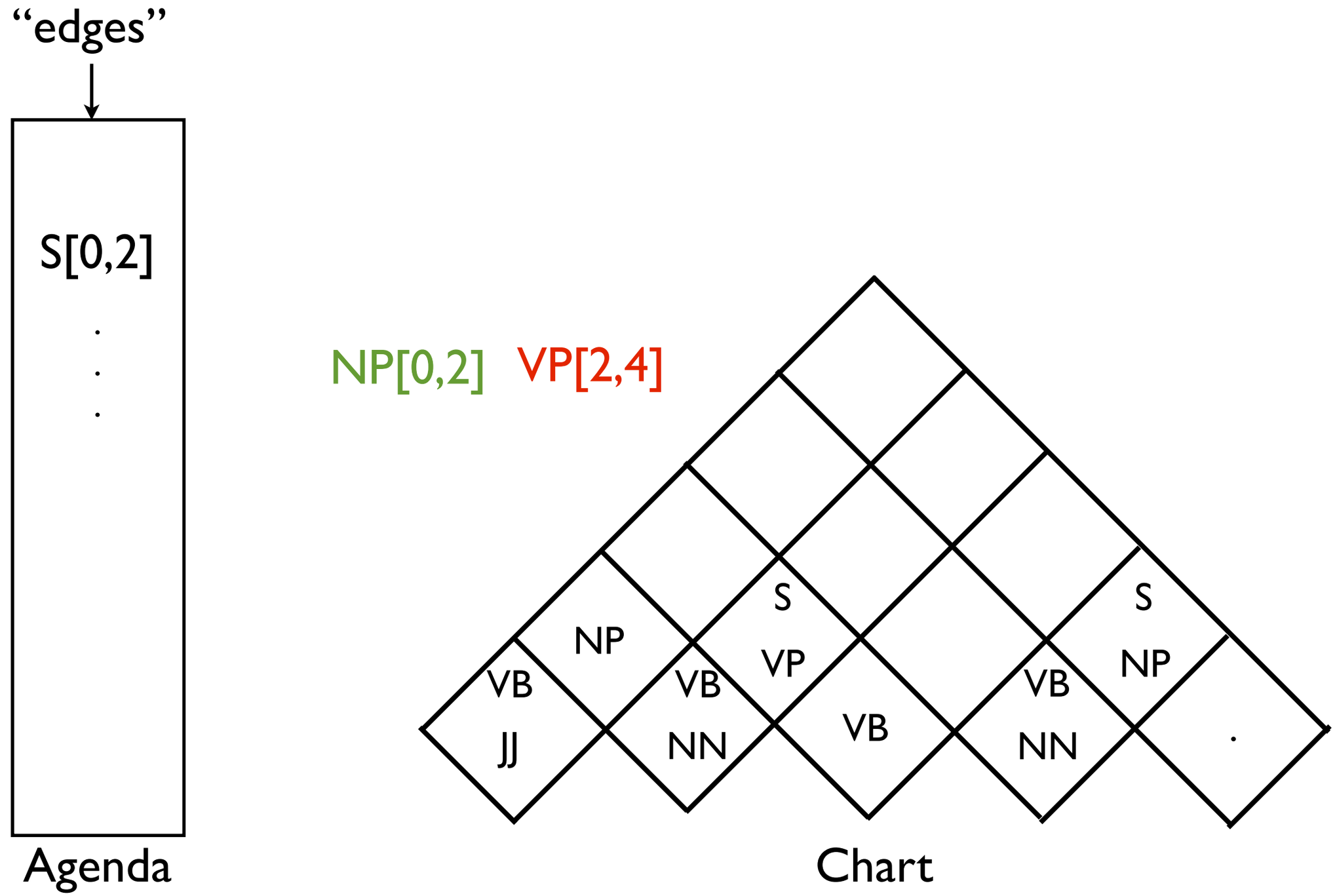

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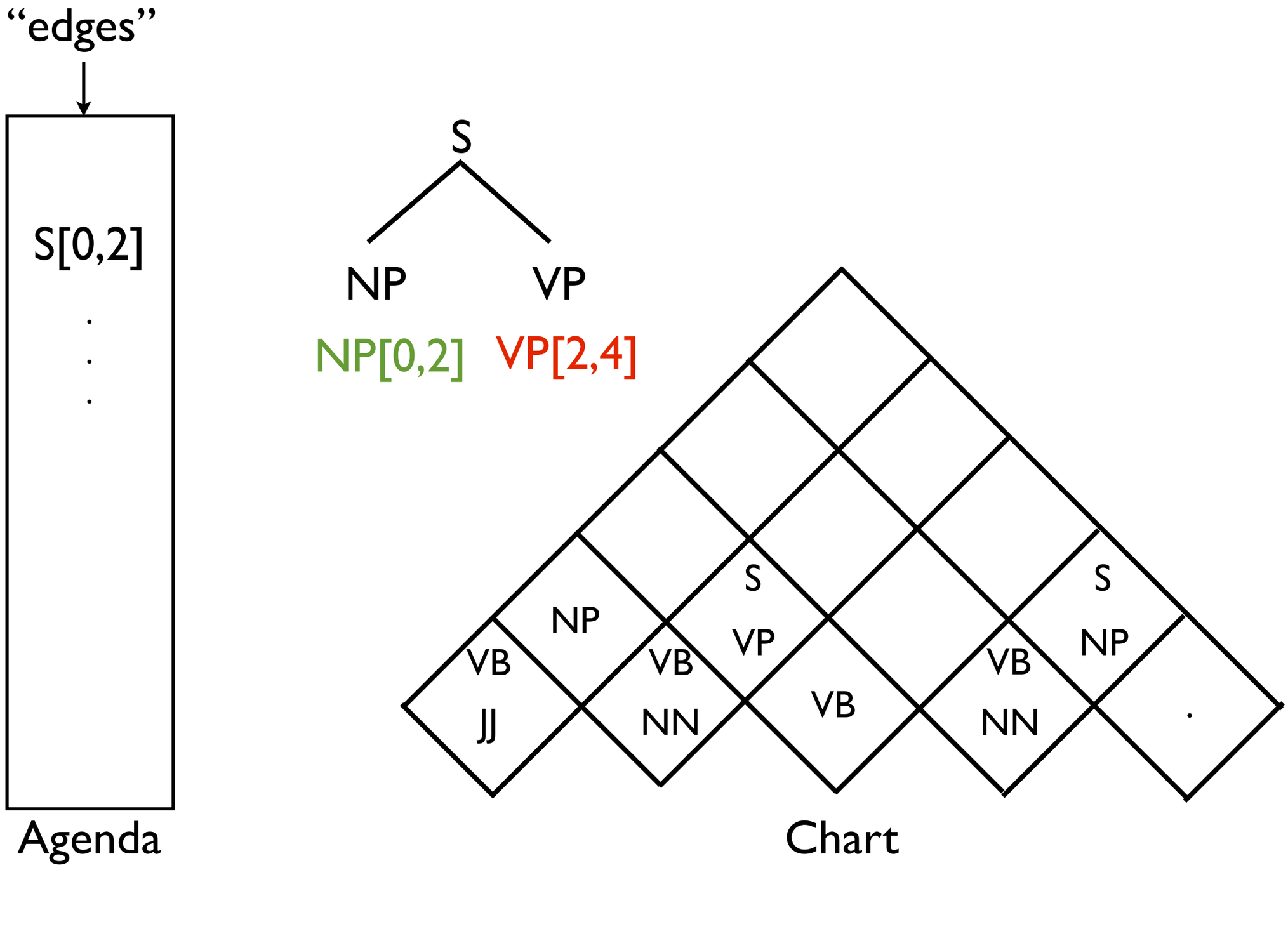

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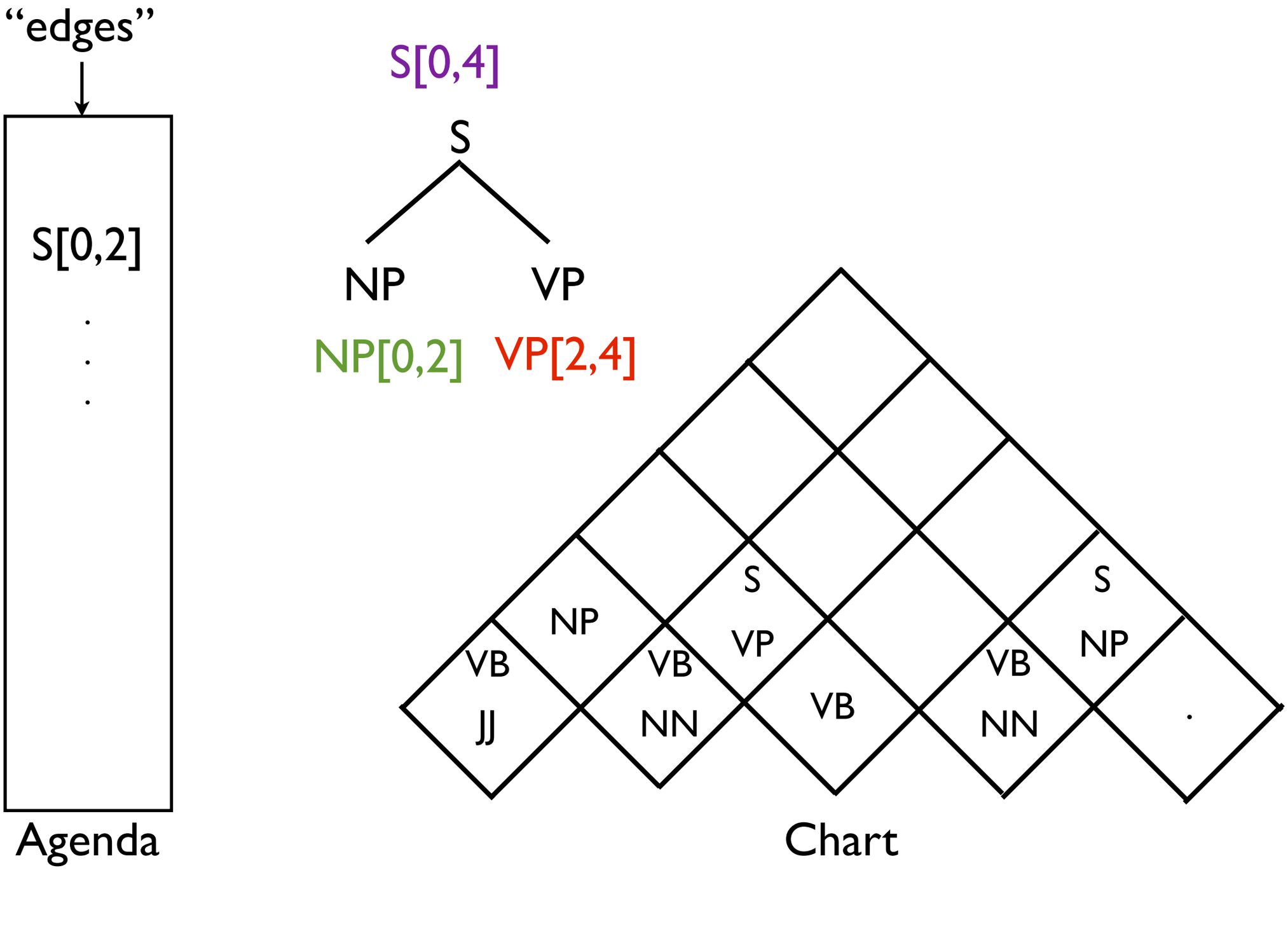

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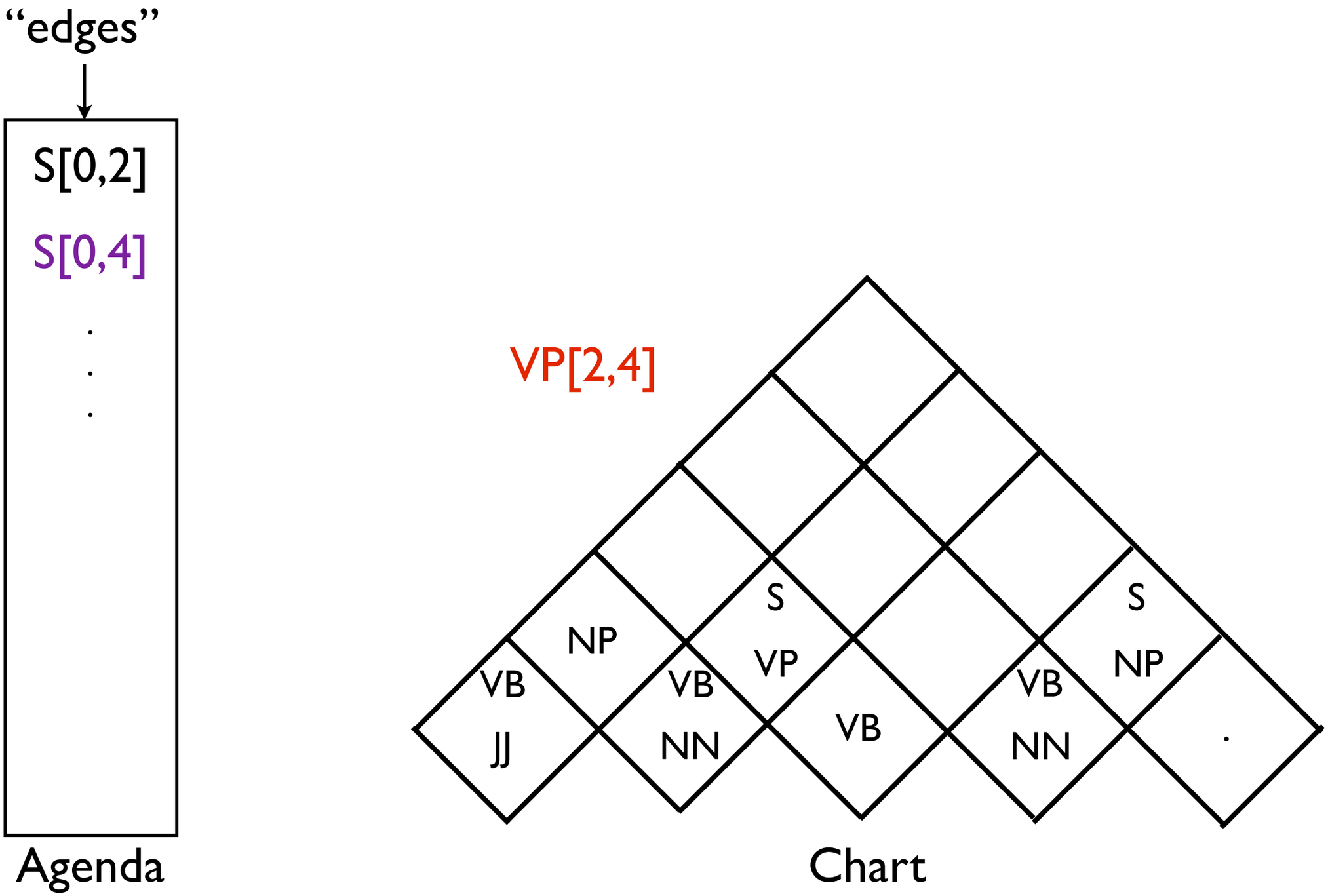

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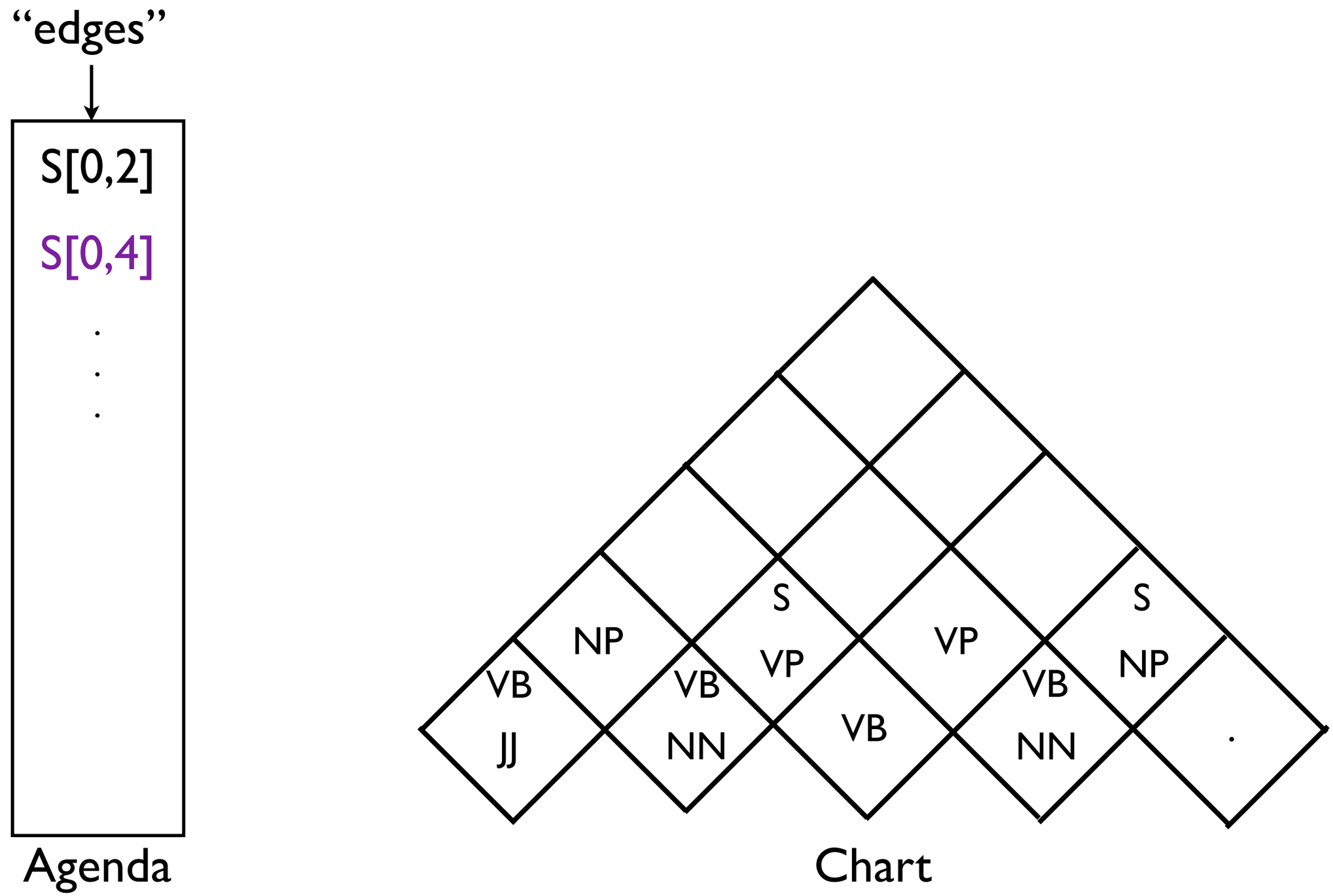

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Building Edges

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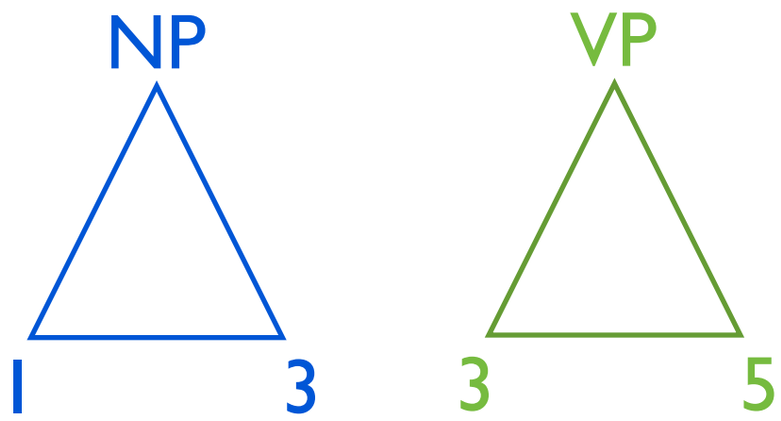

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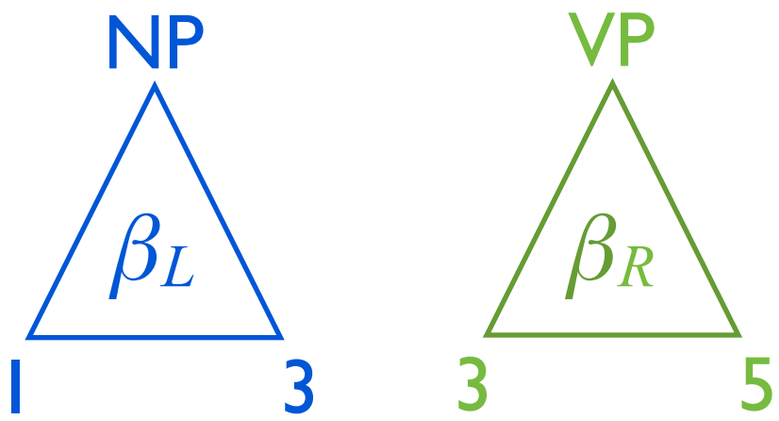

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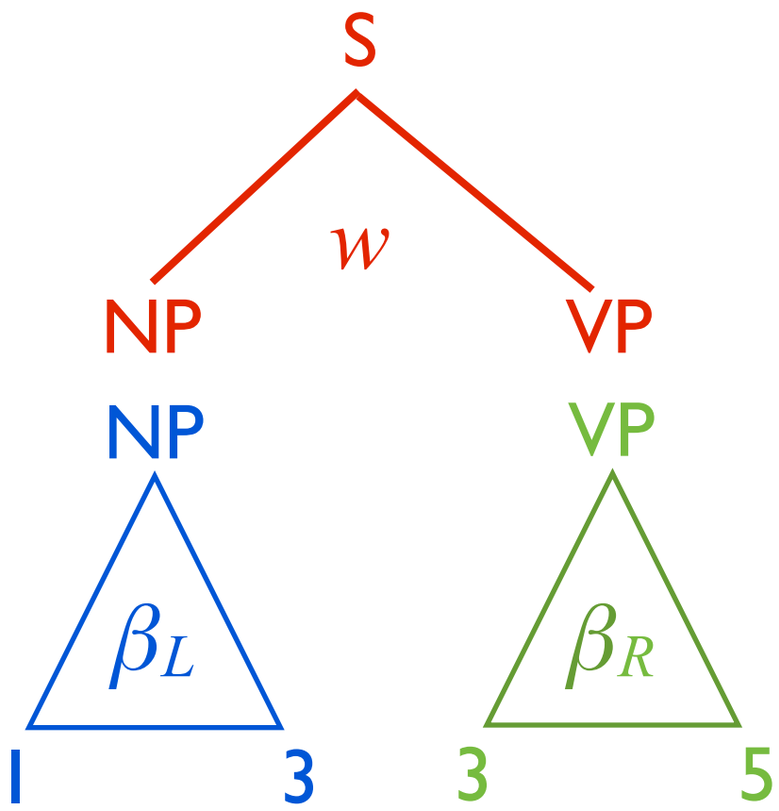

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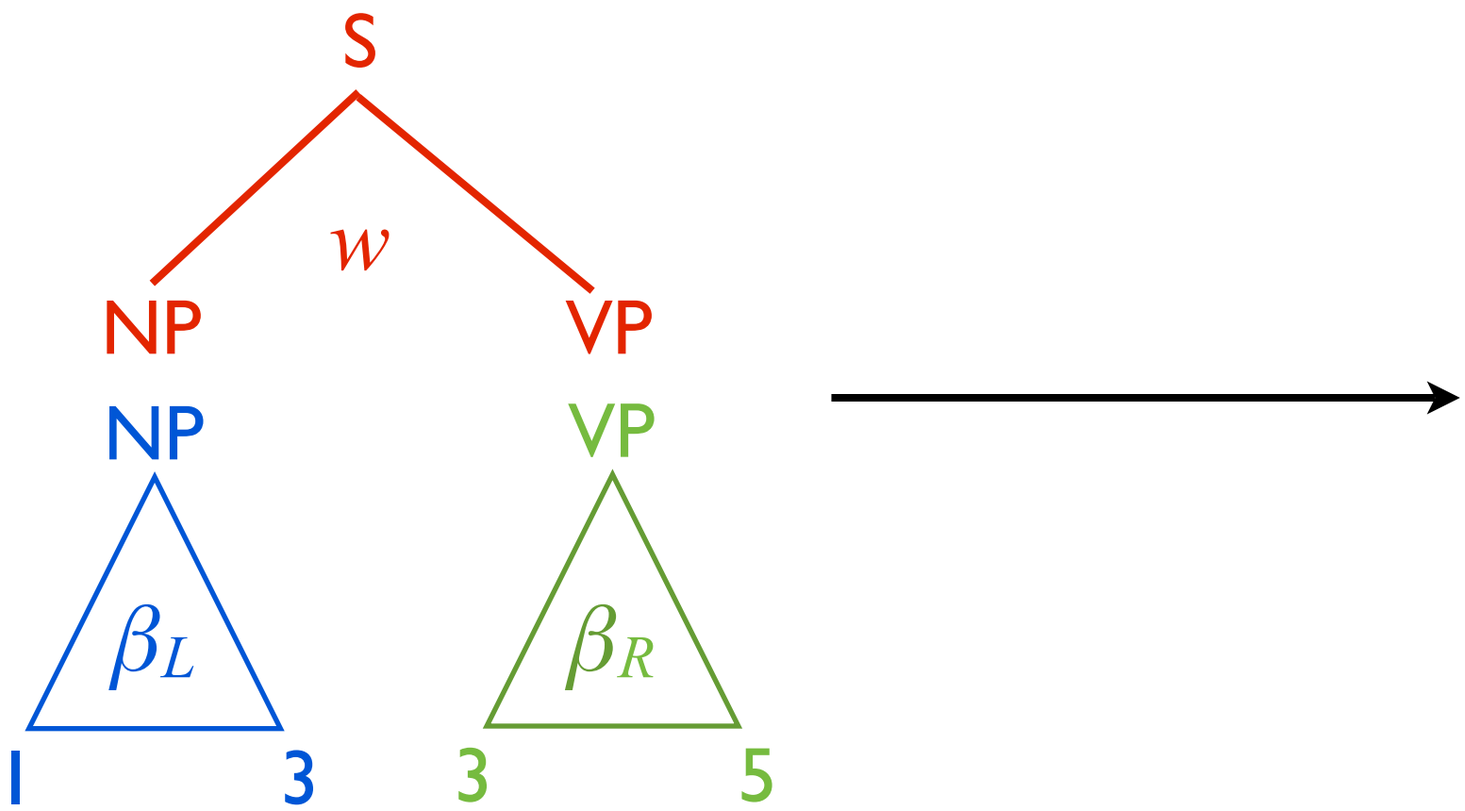

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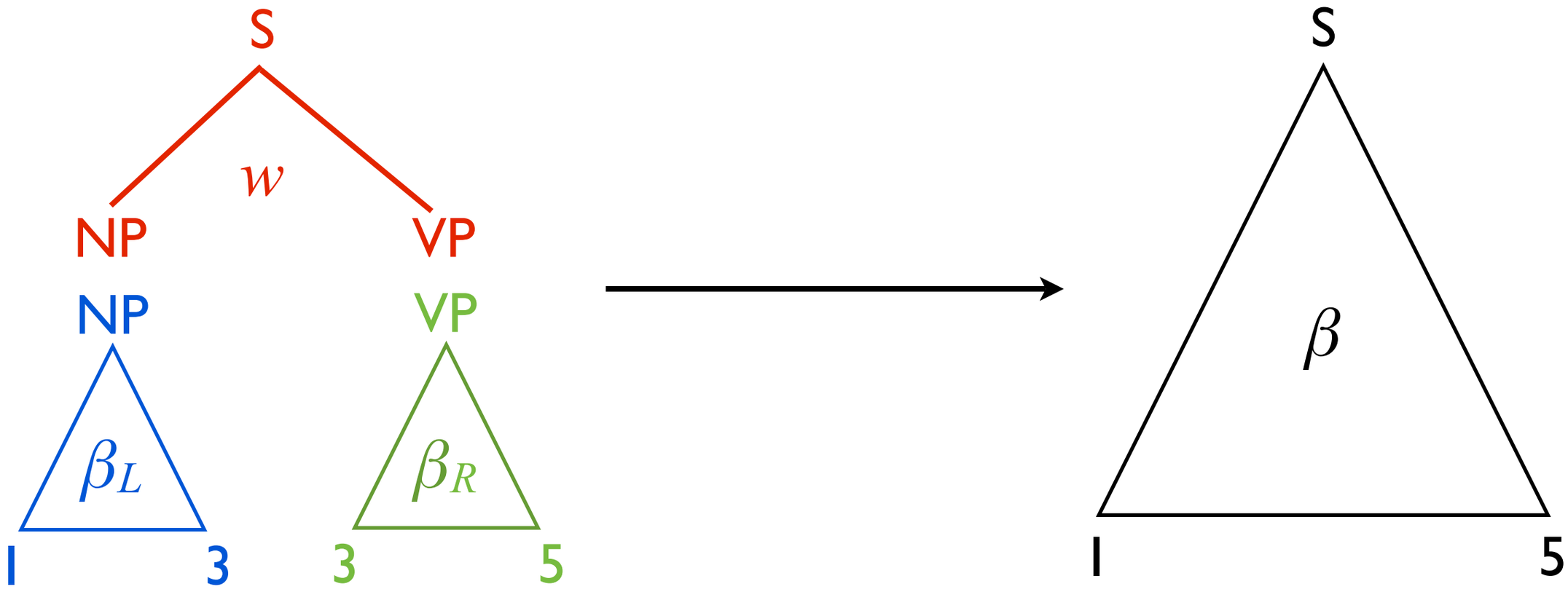

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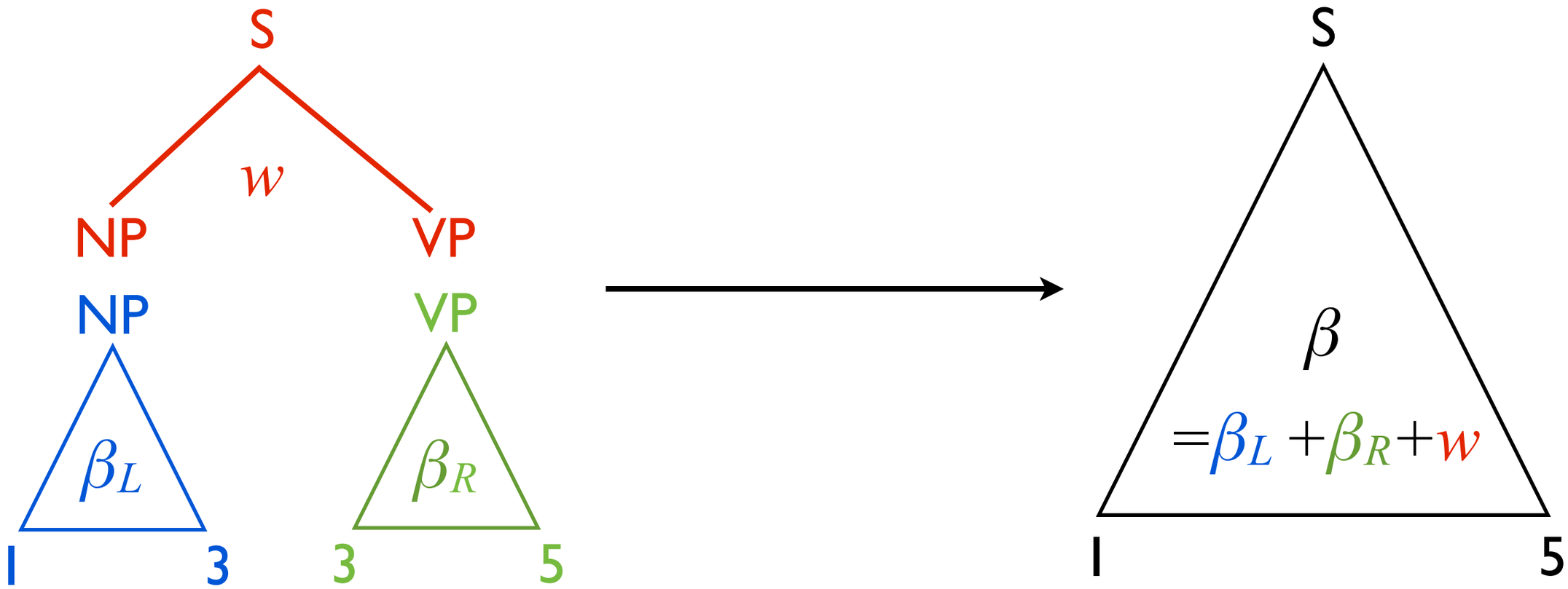

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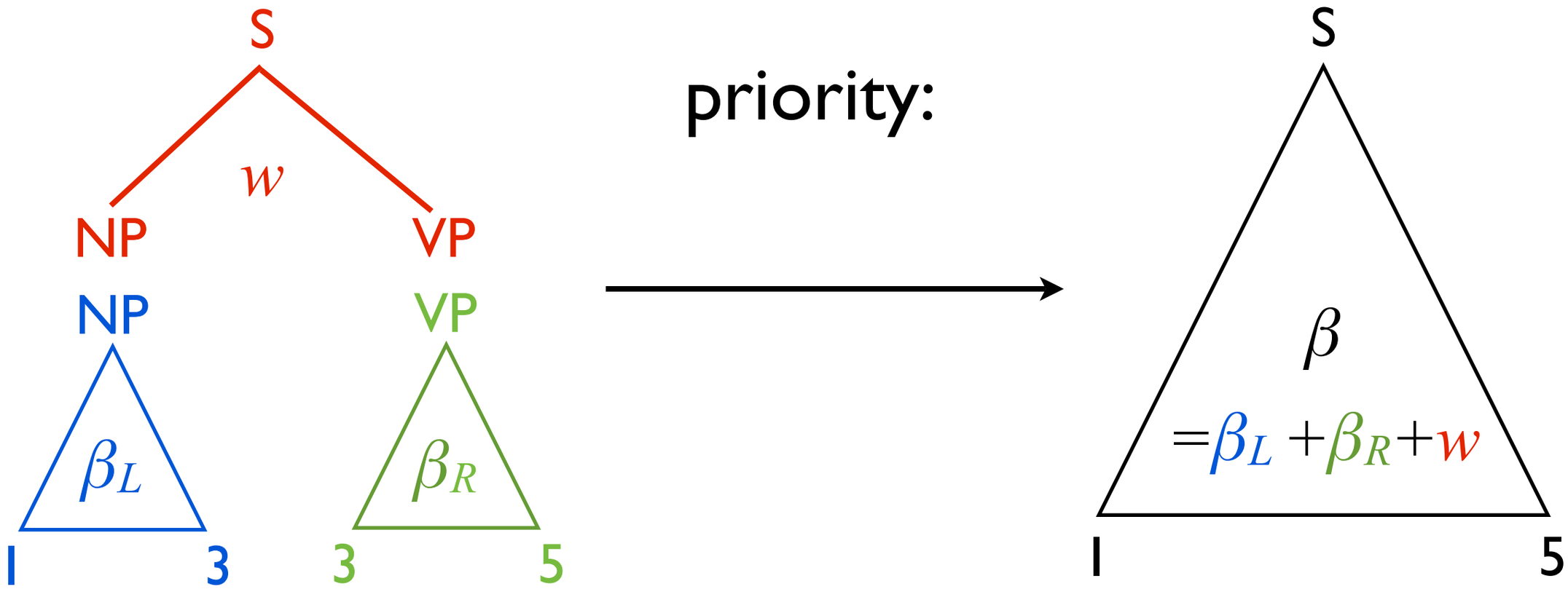

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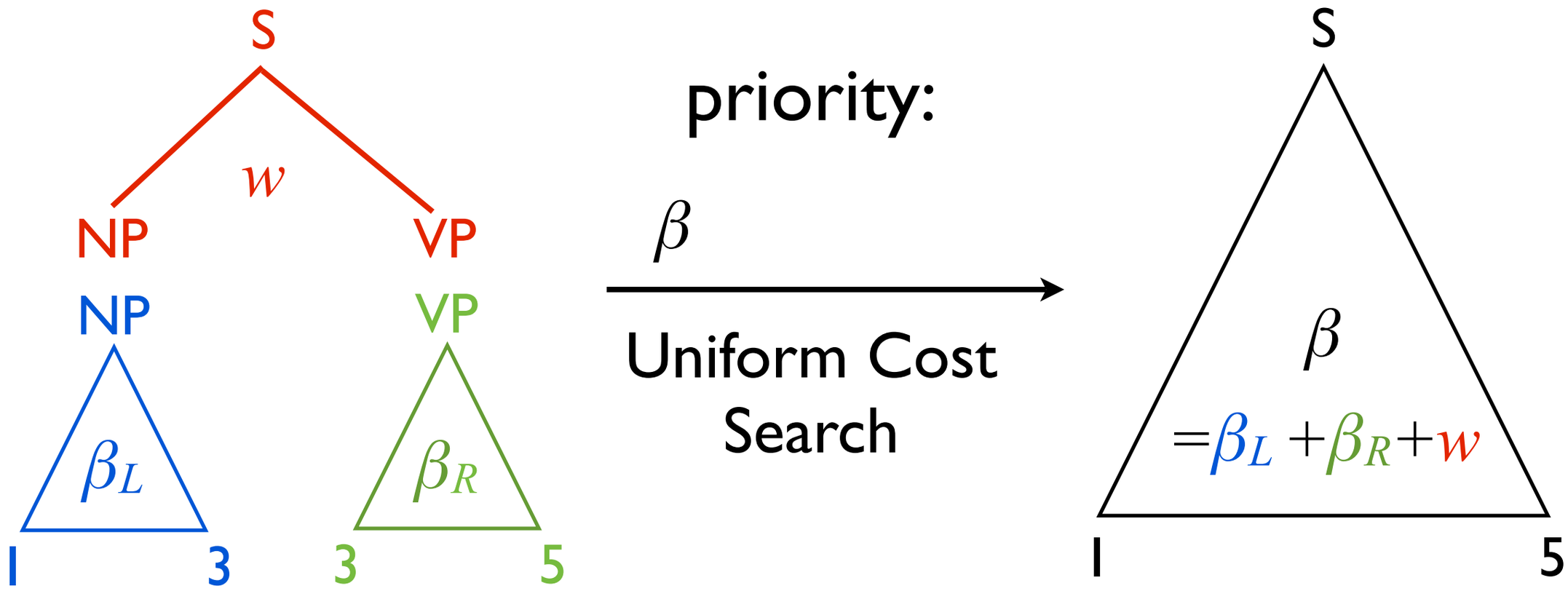

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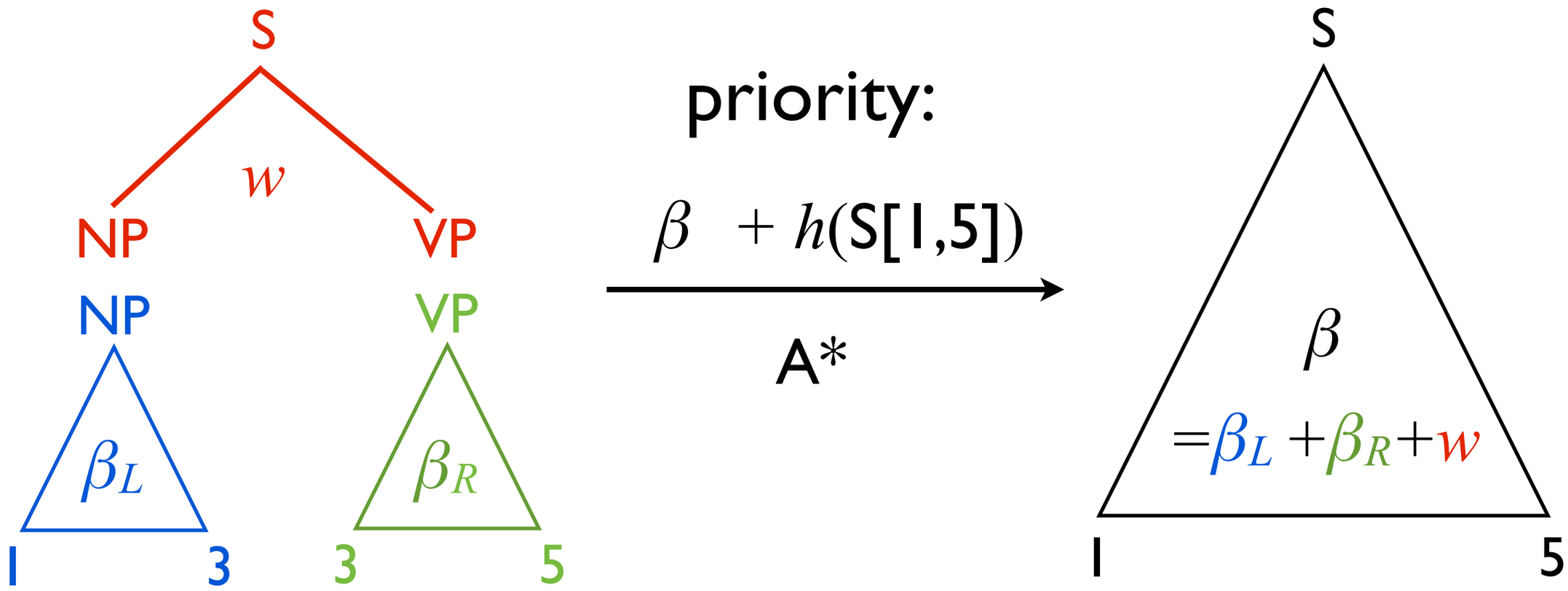

Heuristics

- h is a *heuristic* which lower bounds the Viterbi outside cost α

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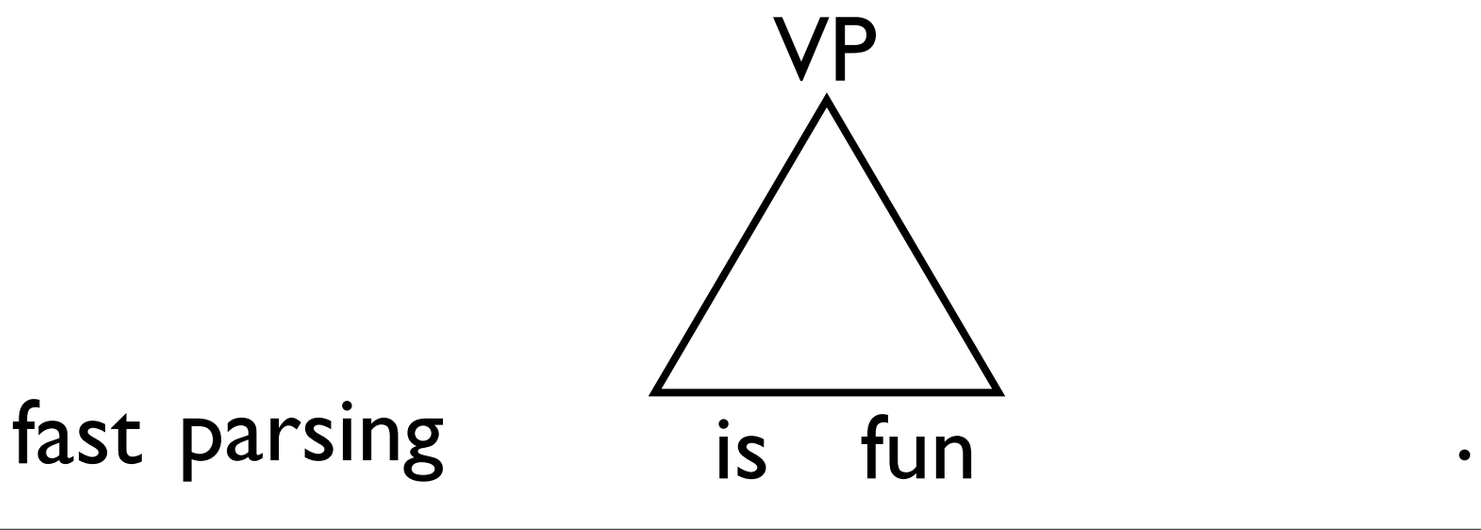

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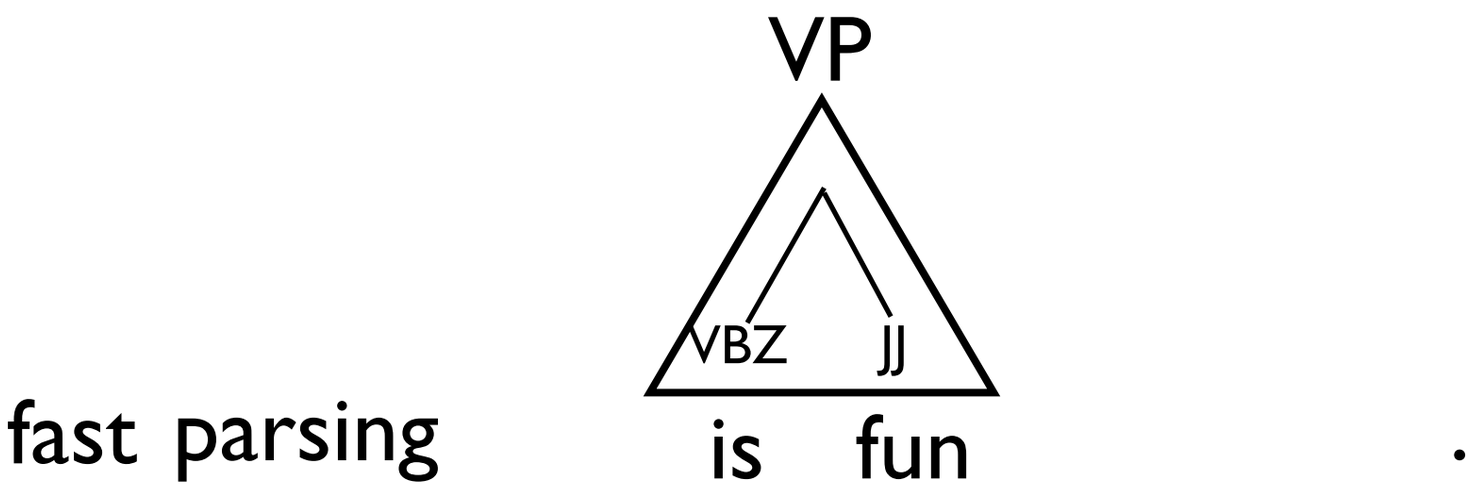

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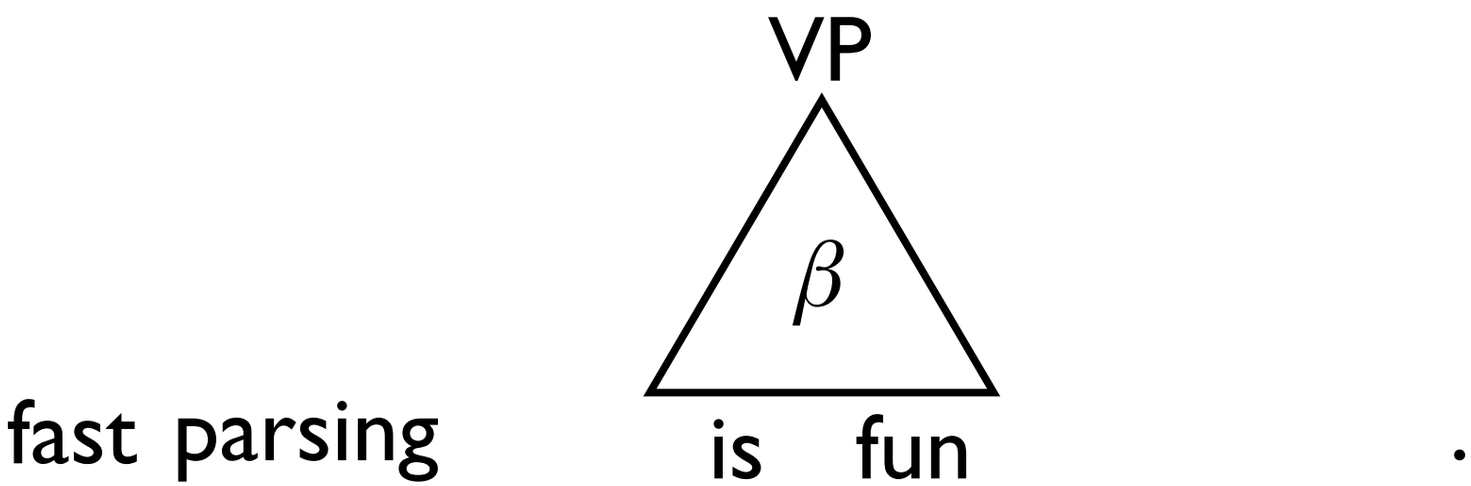

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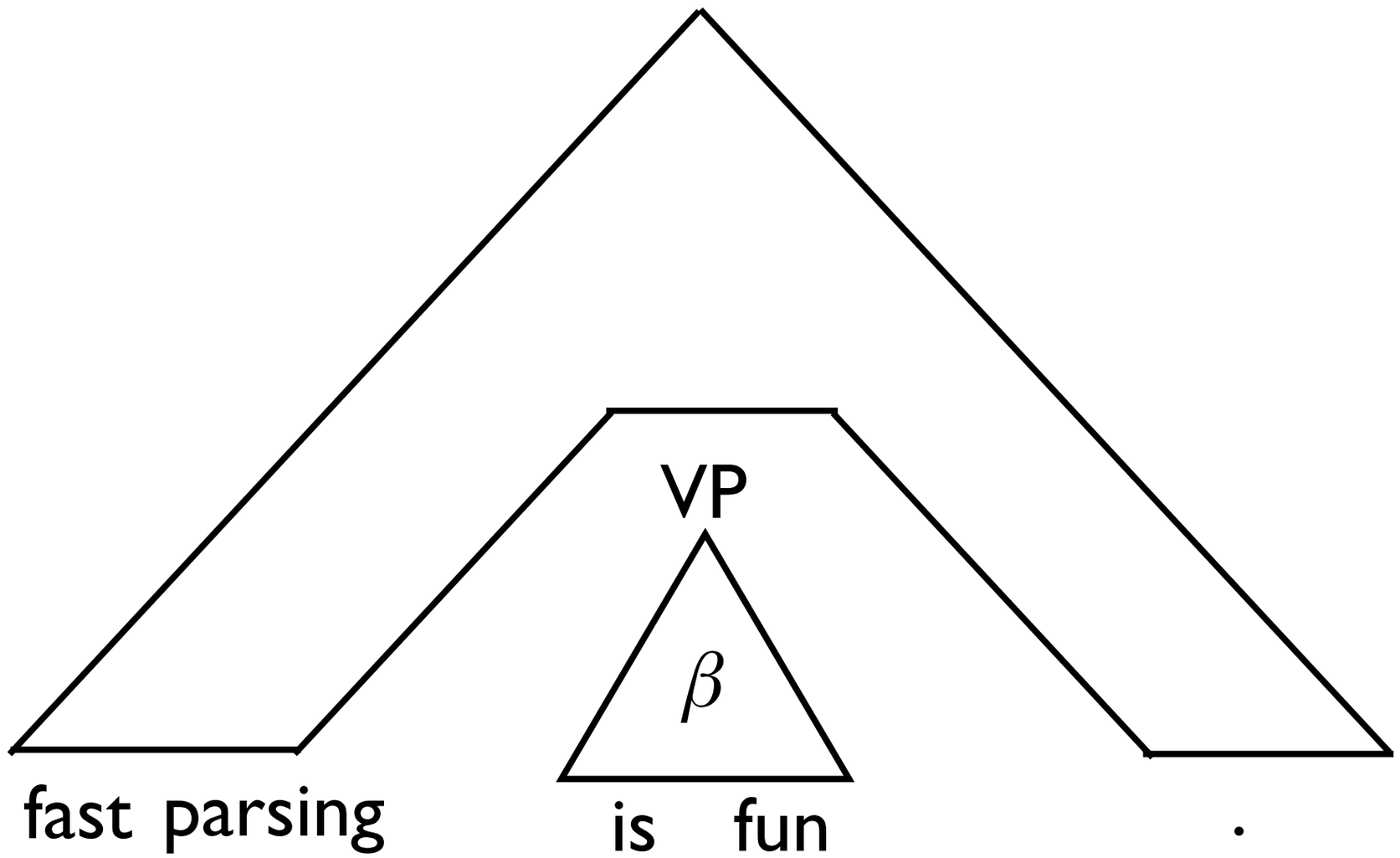

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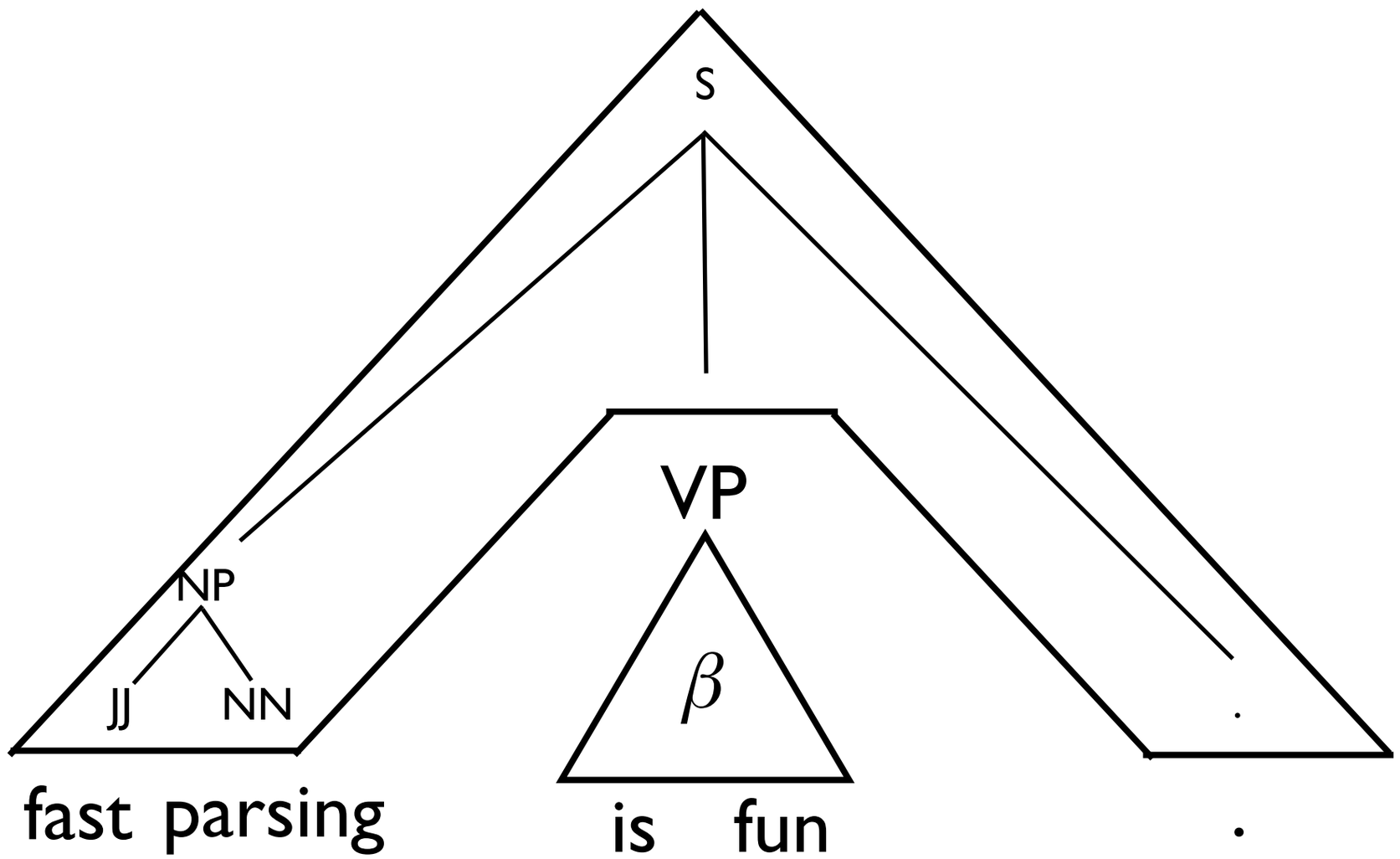

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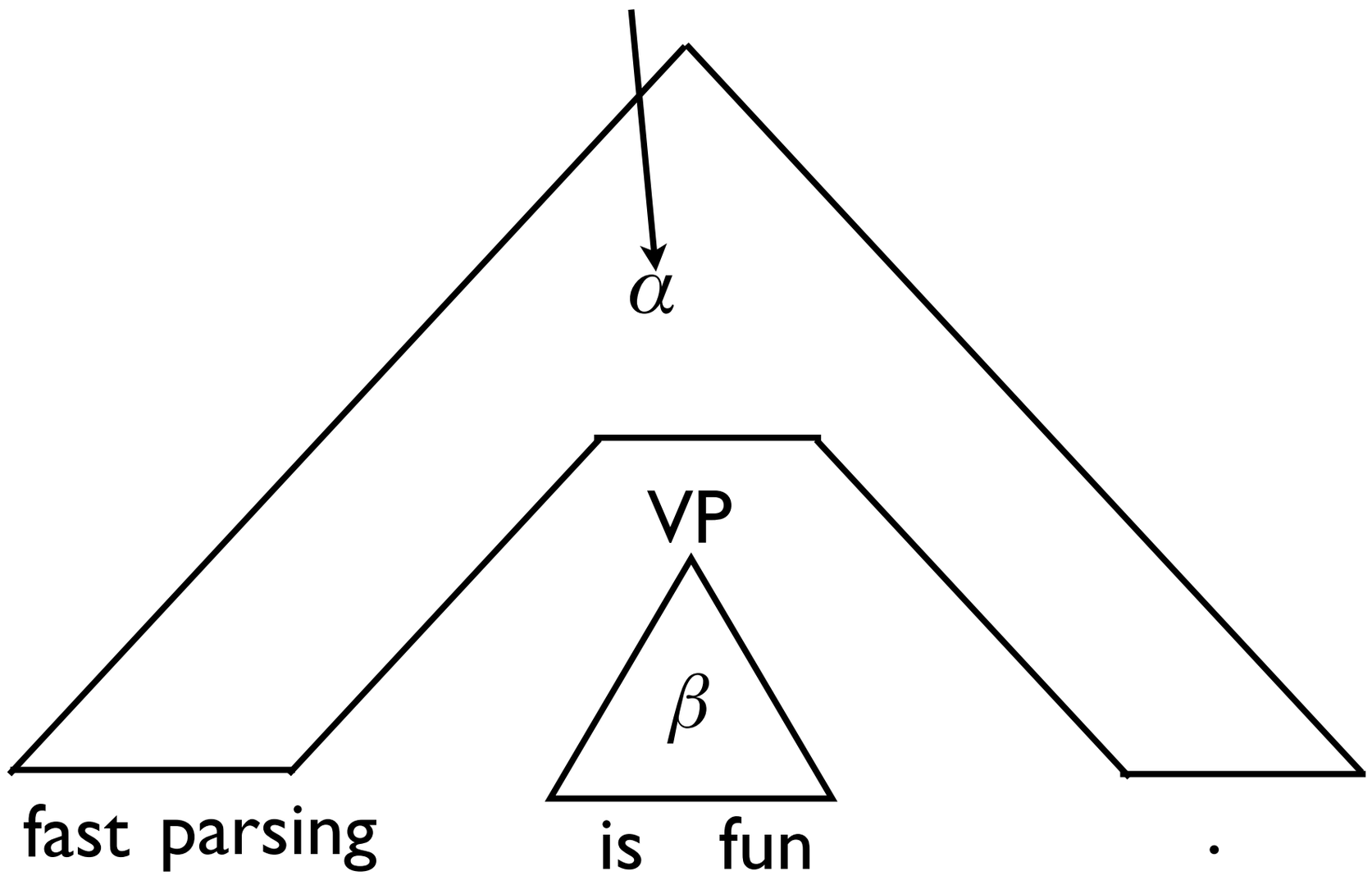

Outside Scores

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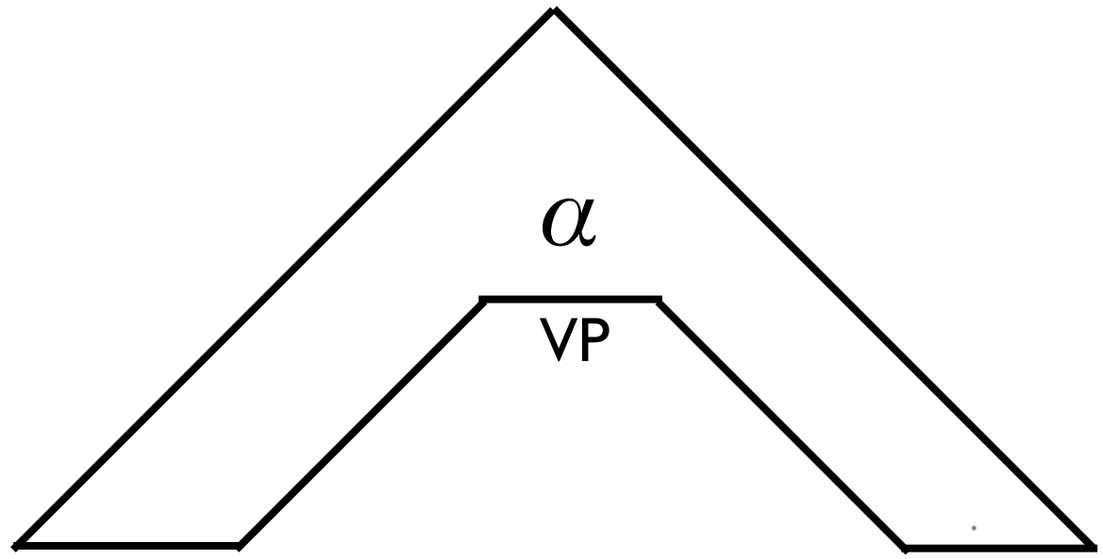

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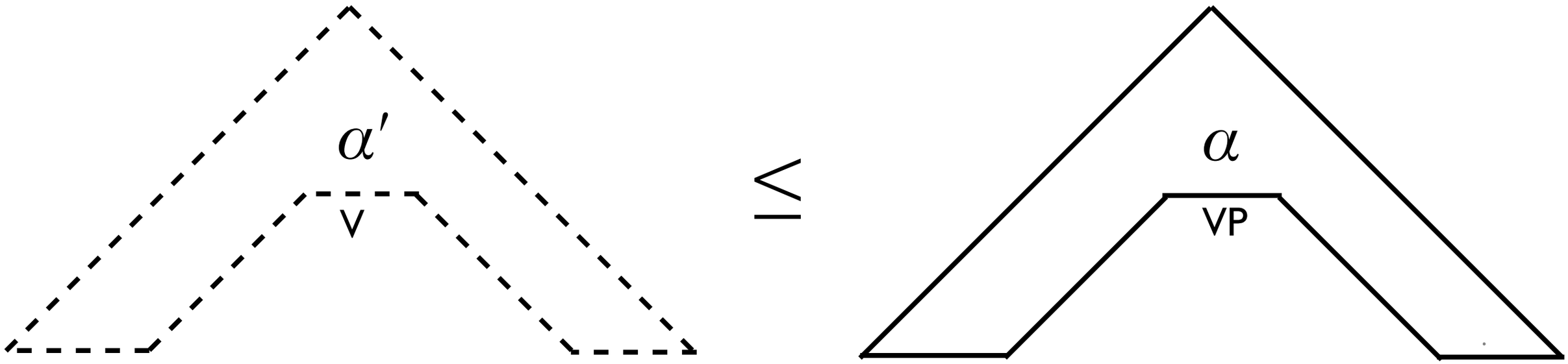

coarse fine

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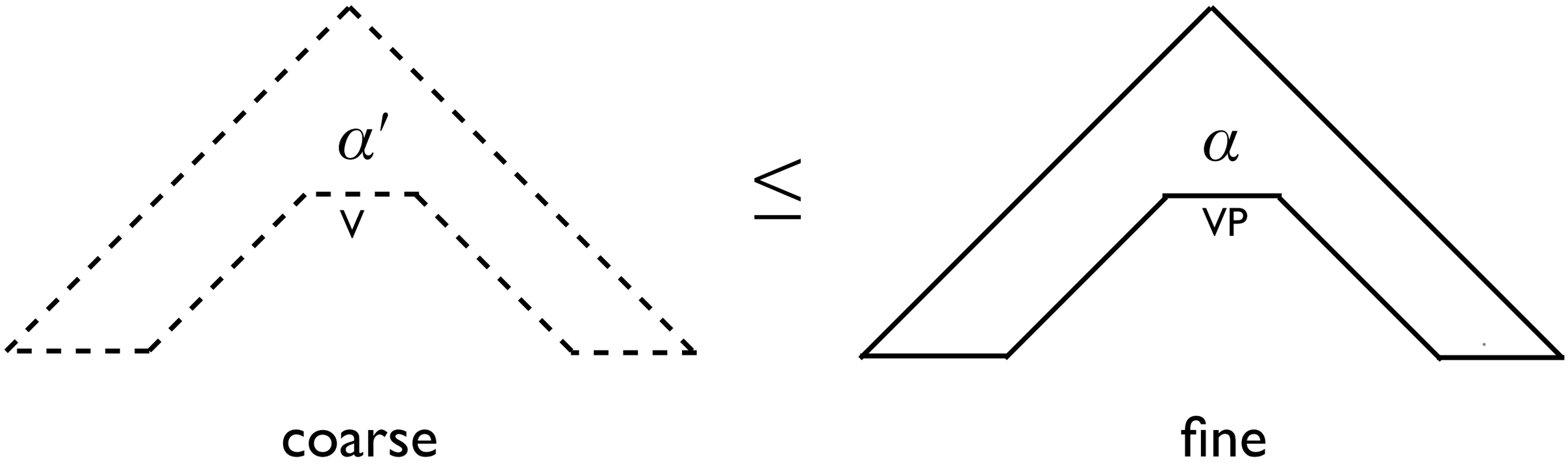
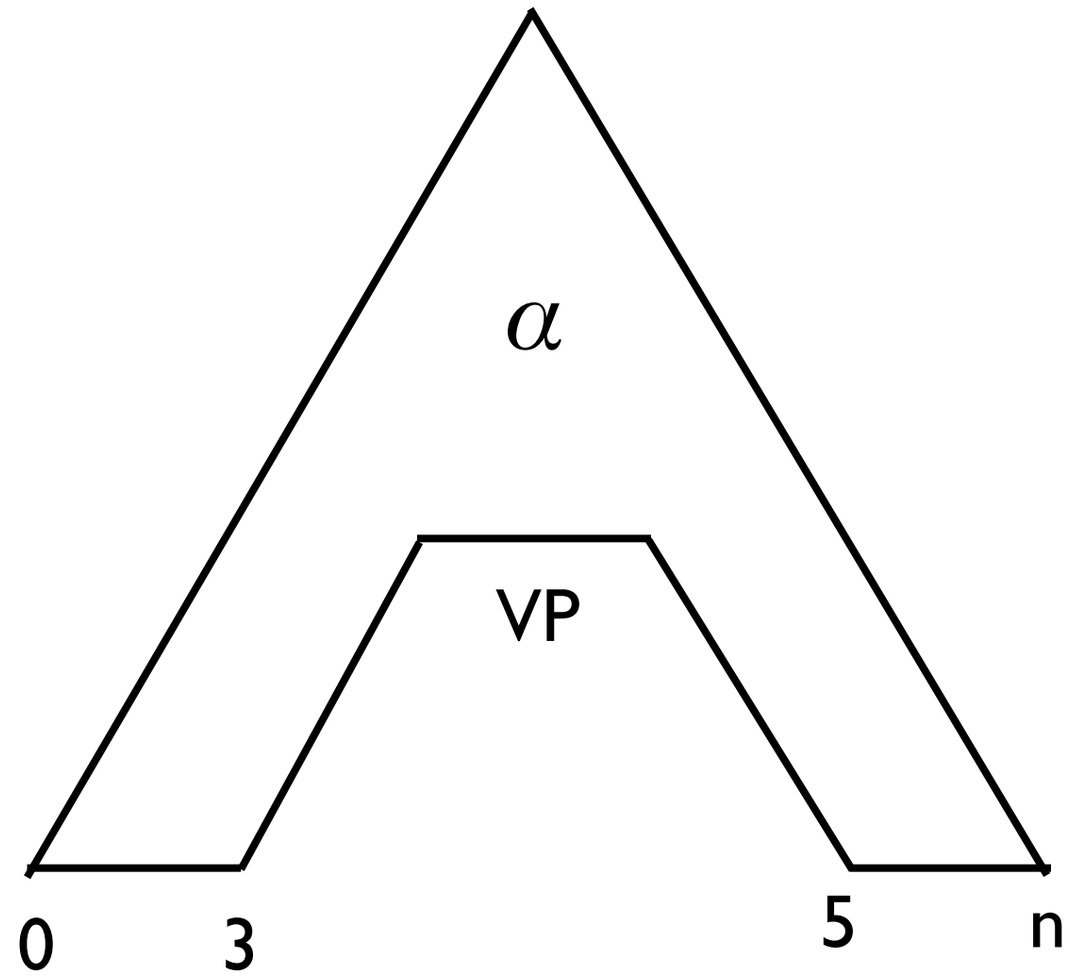


- How do we compute these outside scores?

Building Outside Edges



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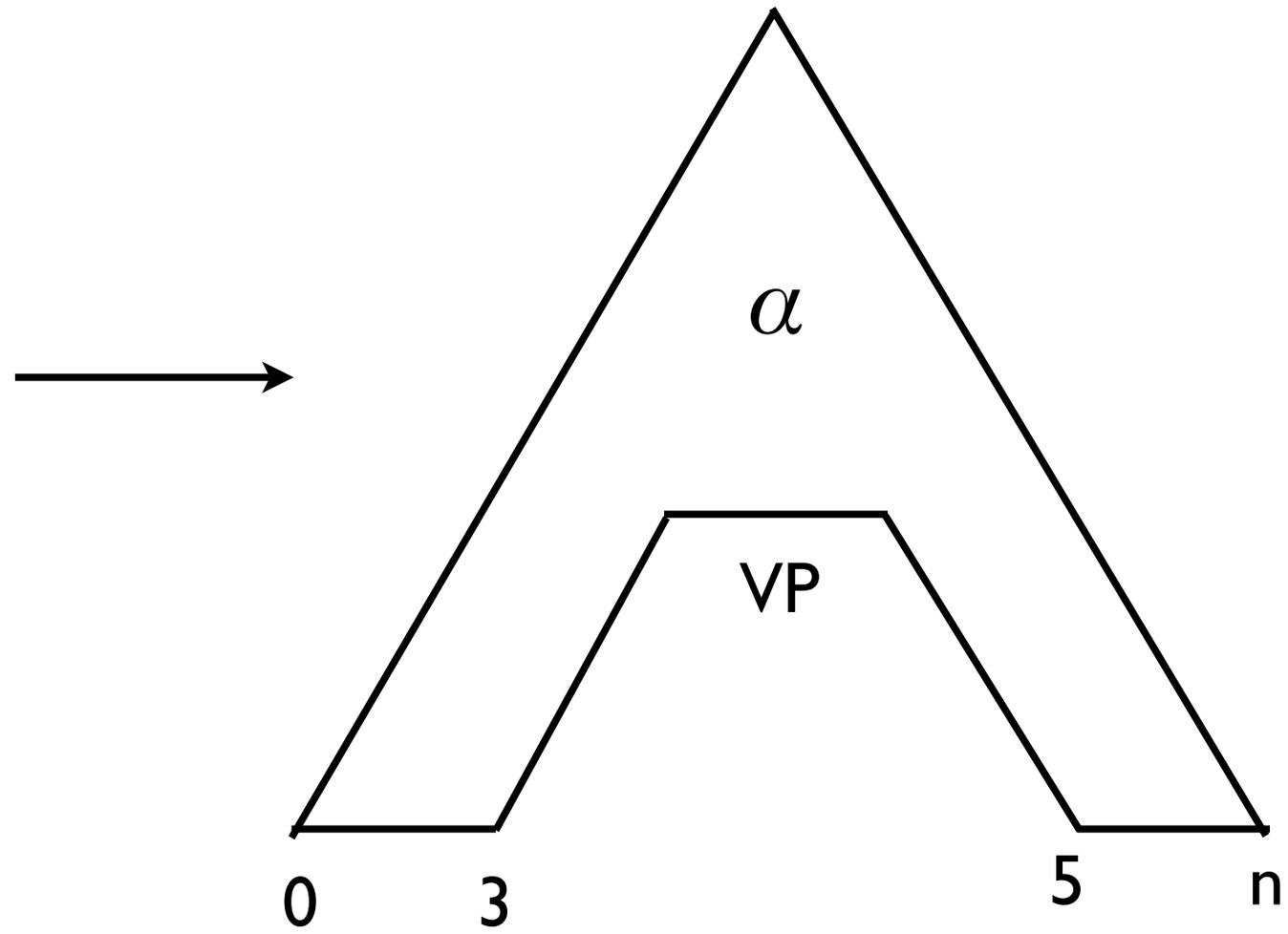

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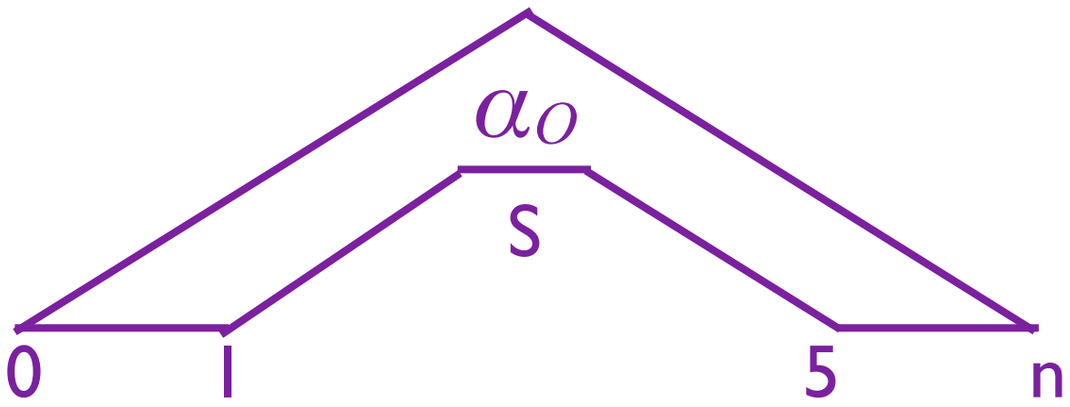

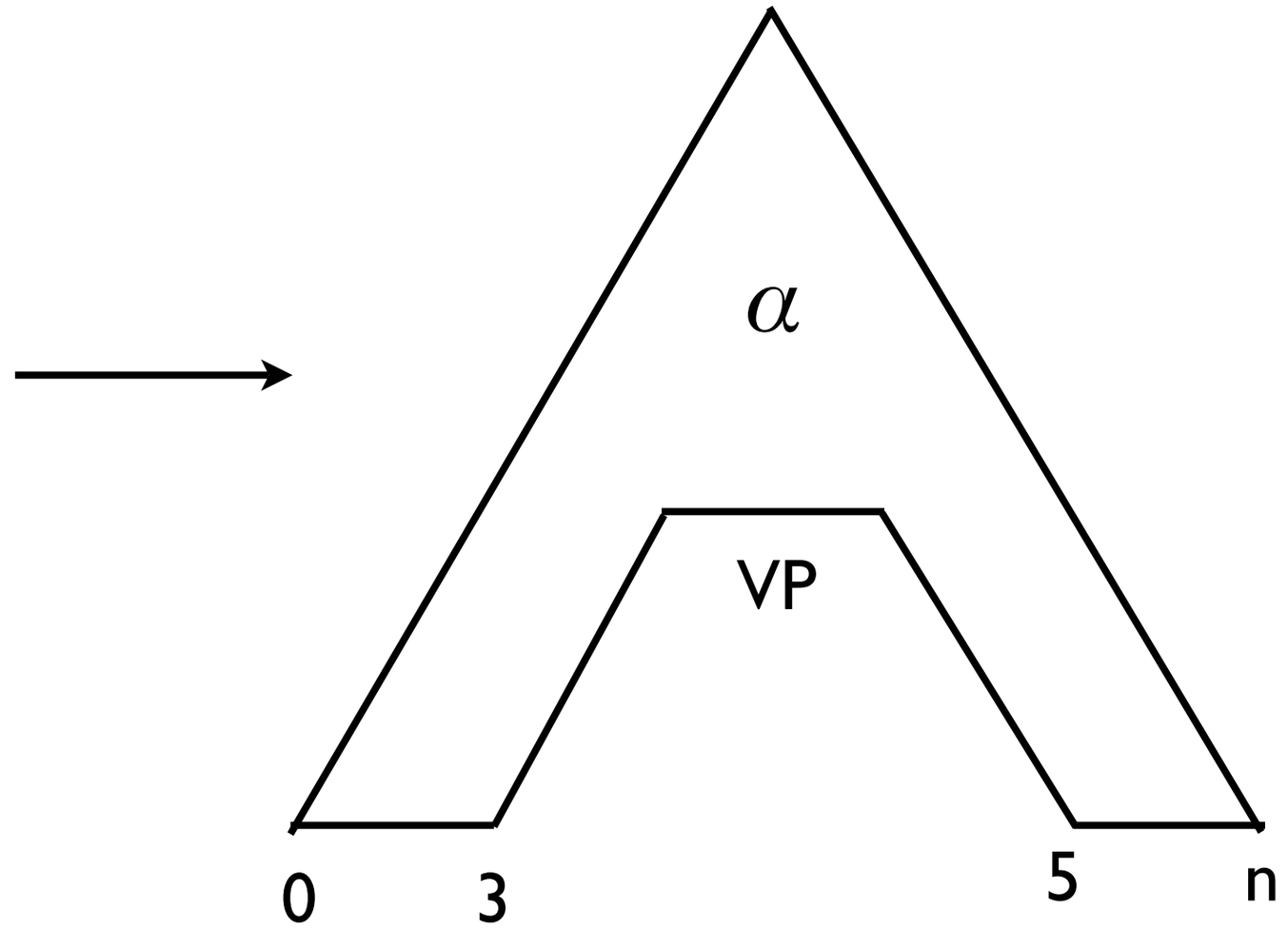

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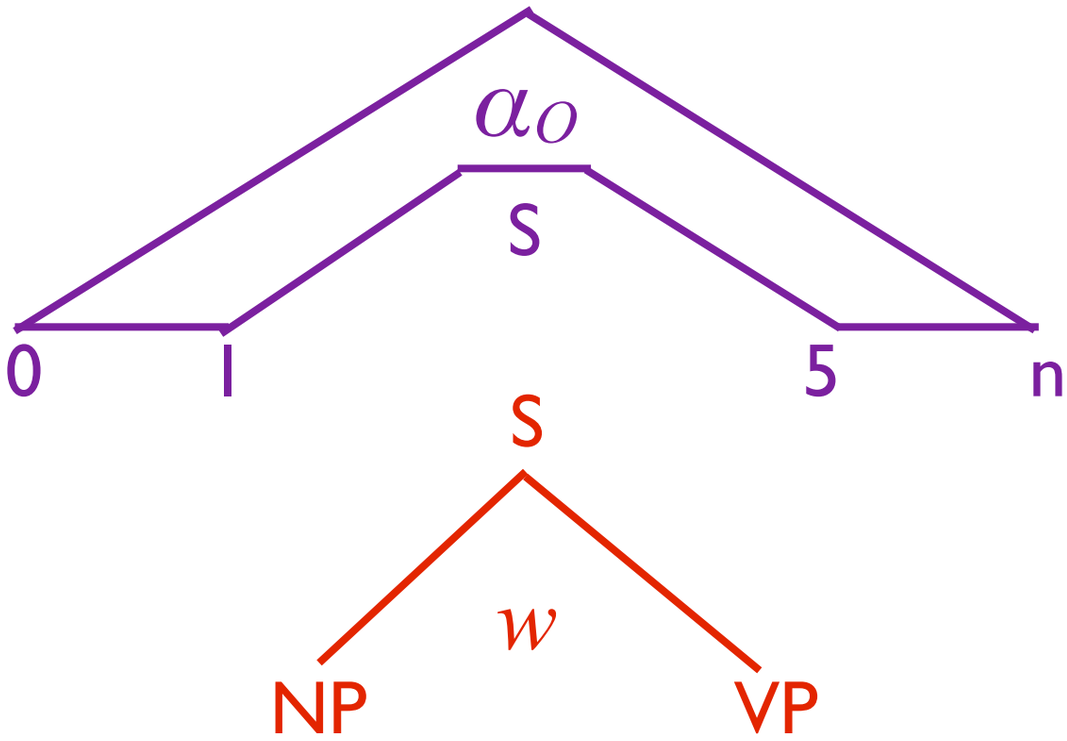

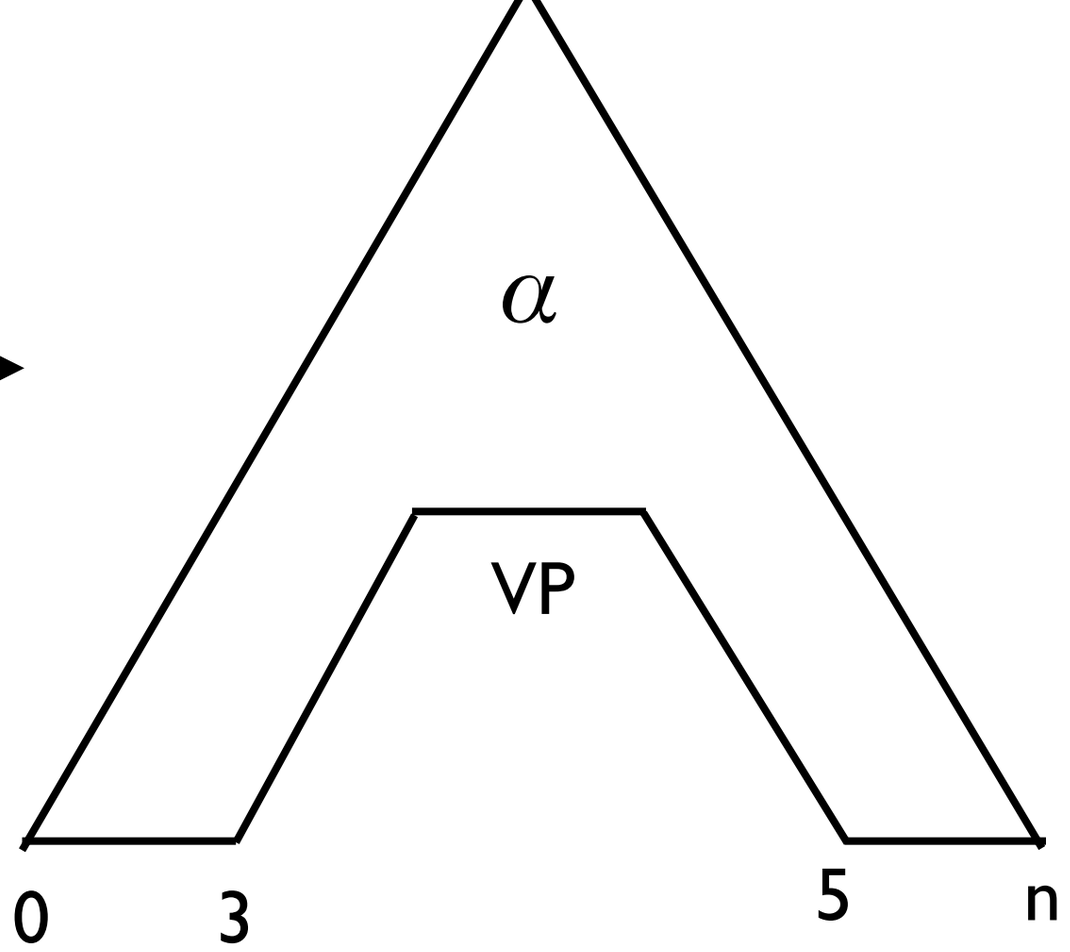

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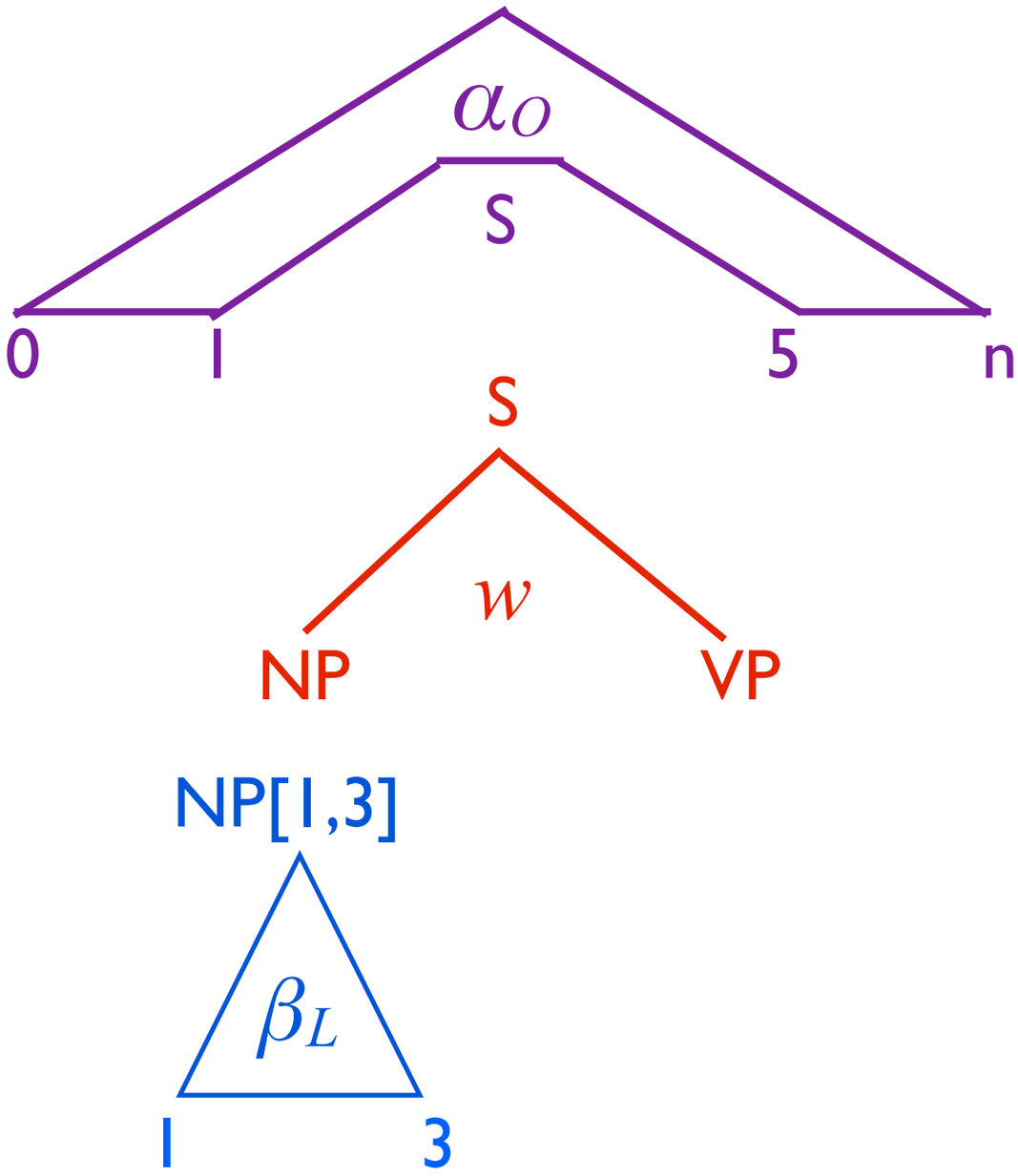

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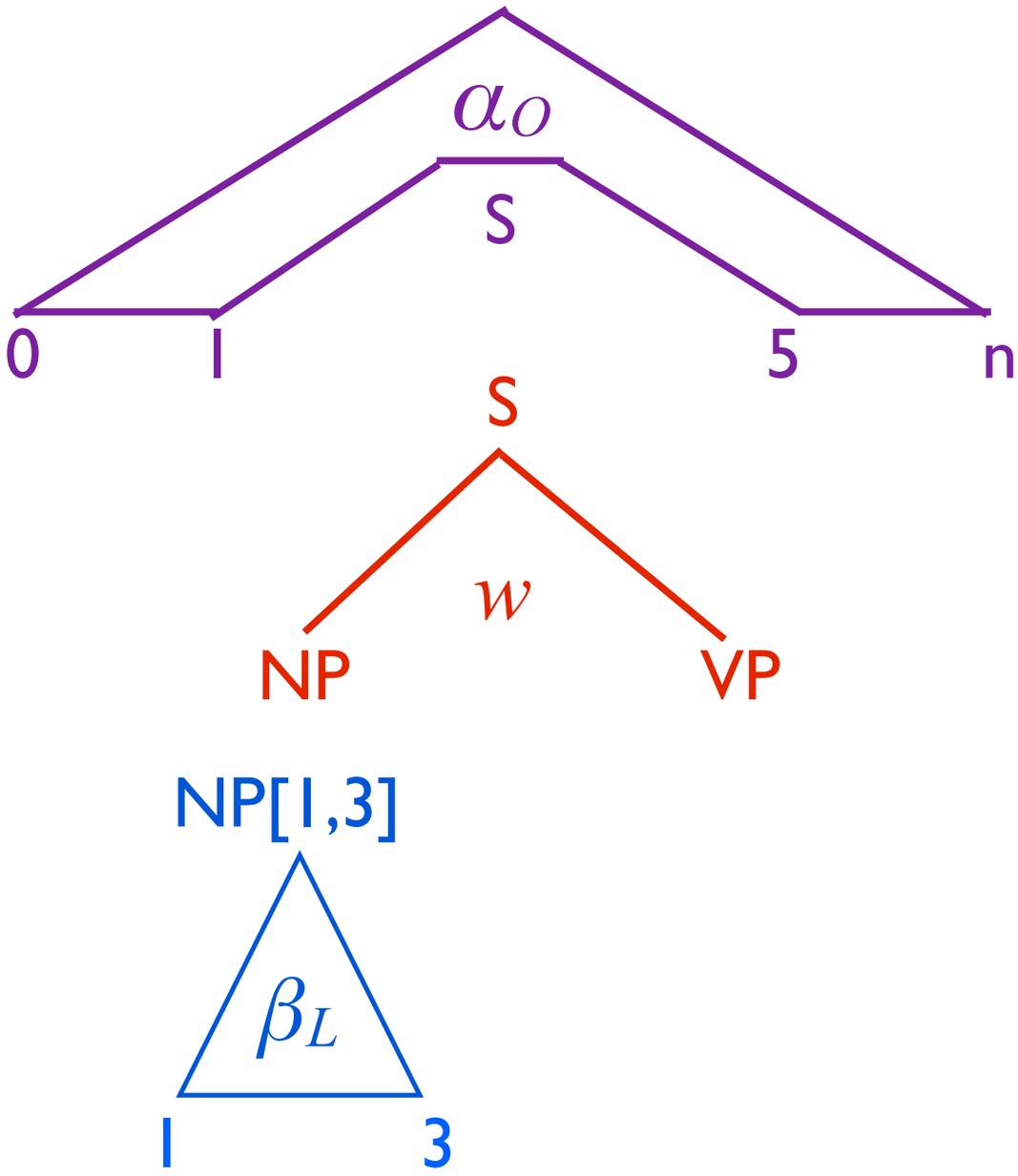
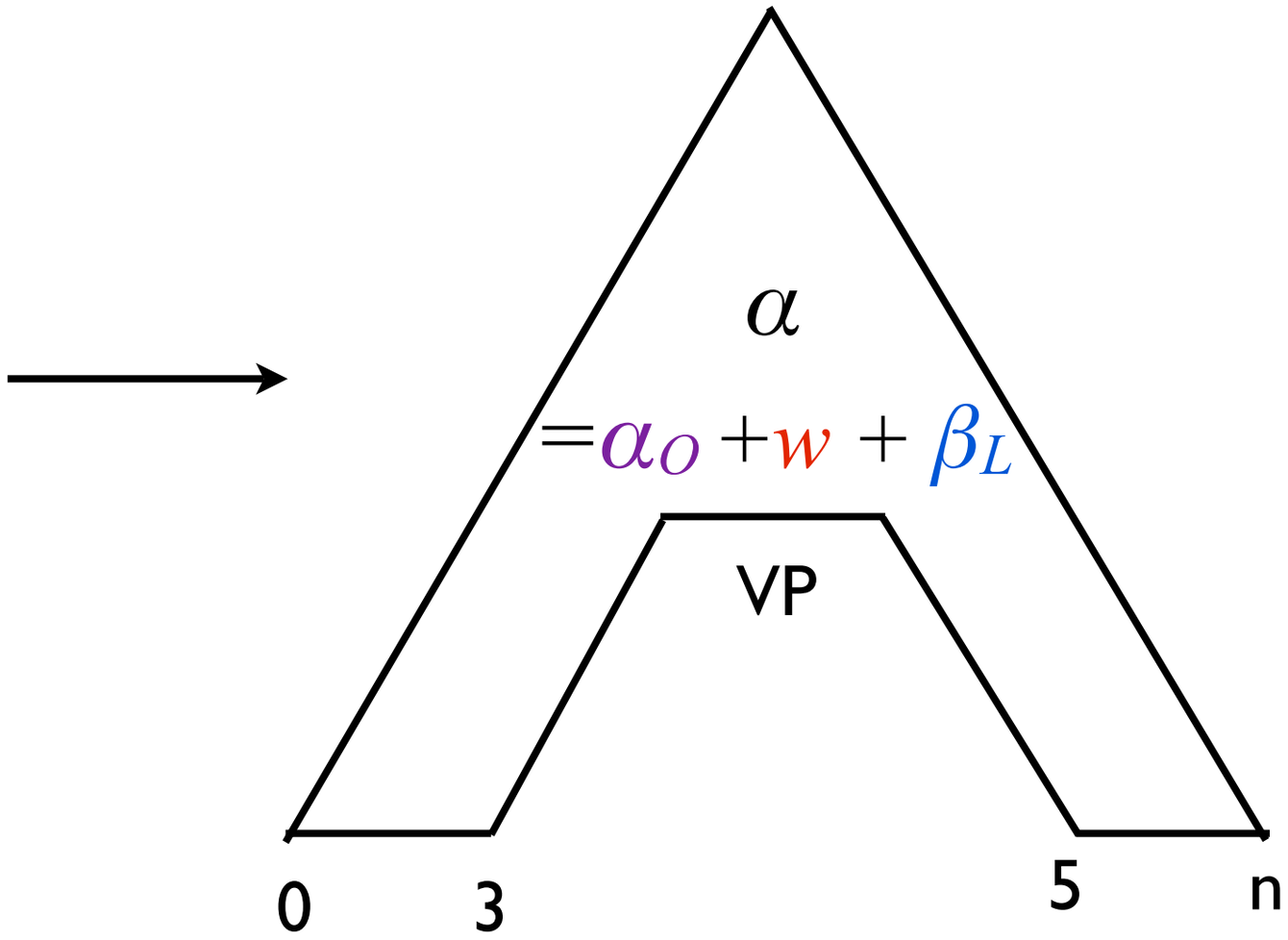
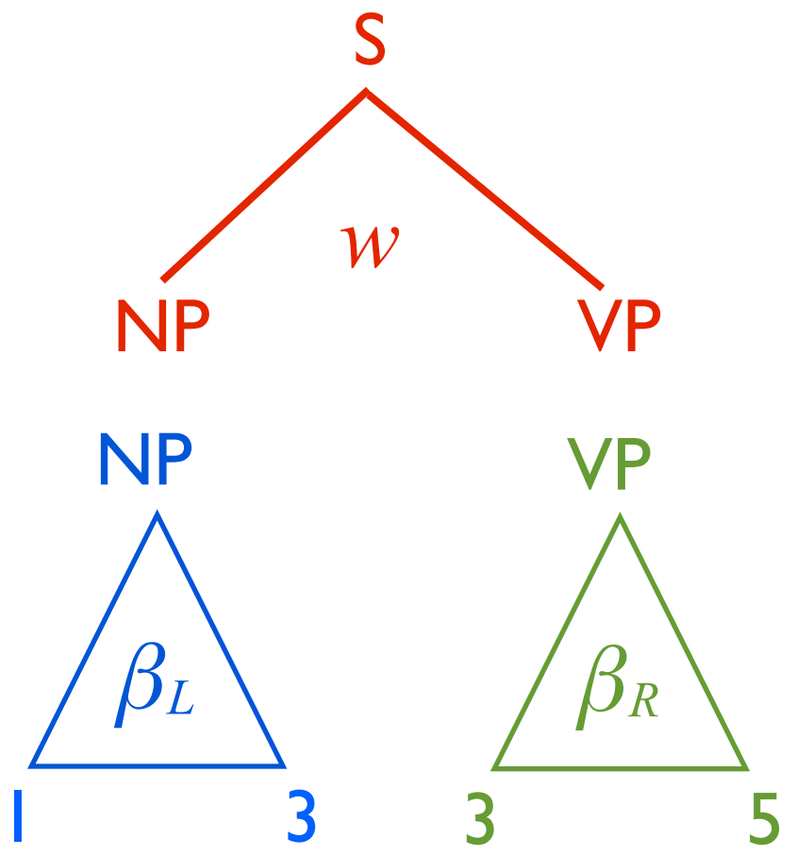




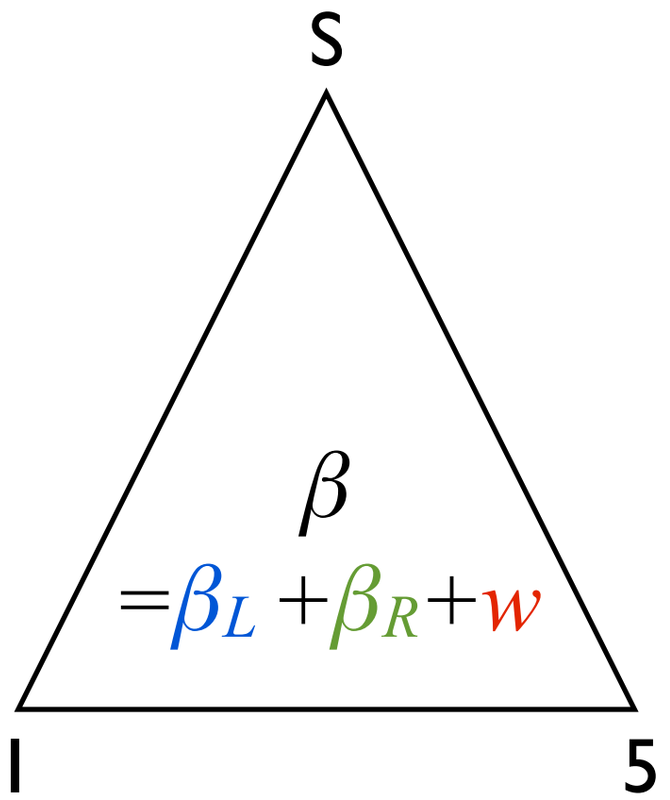
Hierarchical A* (Felzenswalb and McAllester 2007)

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

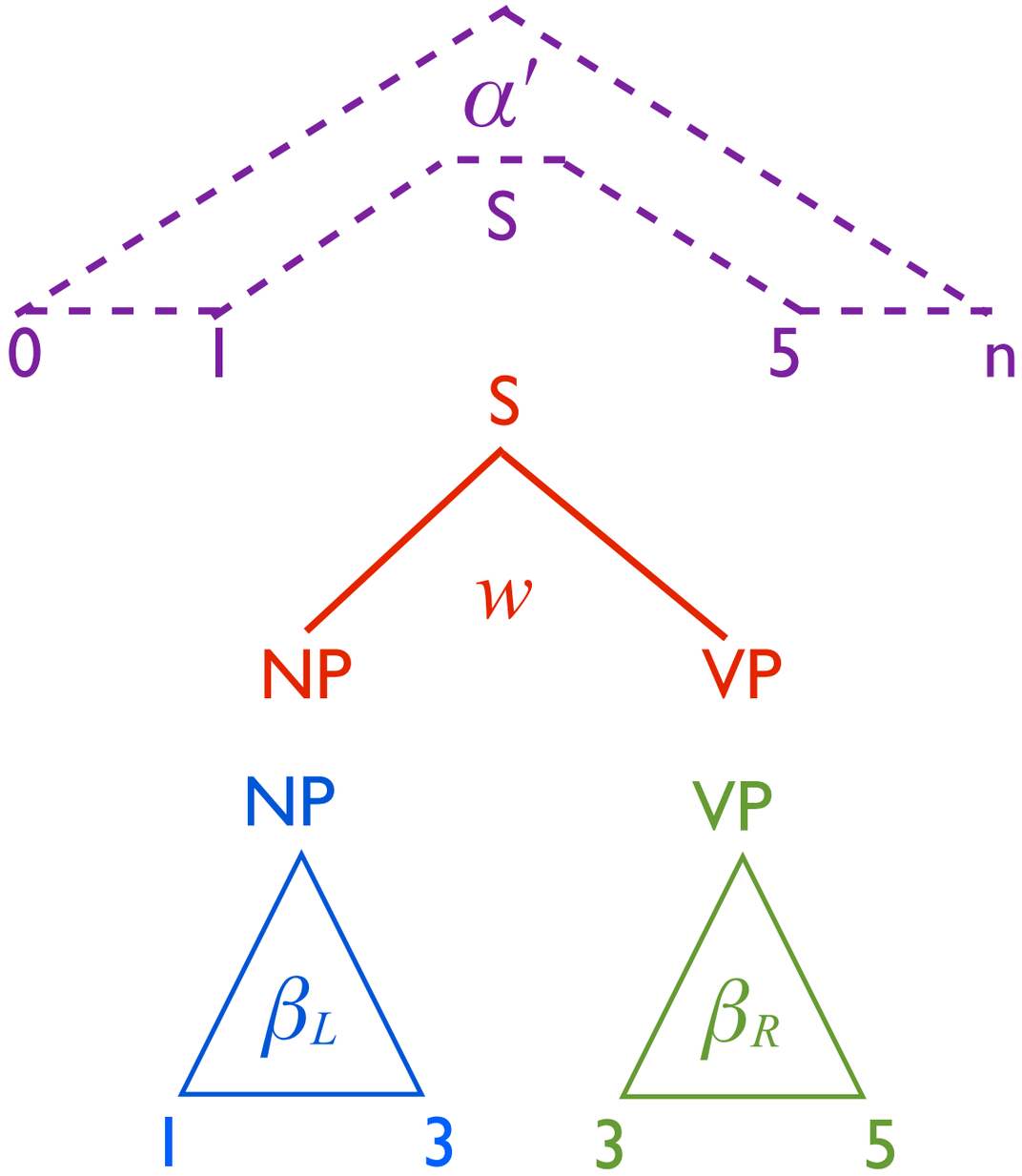
Hierarchically Building Inside Edges



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



Hierarchically Building Inside Edges



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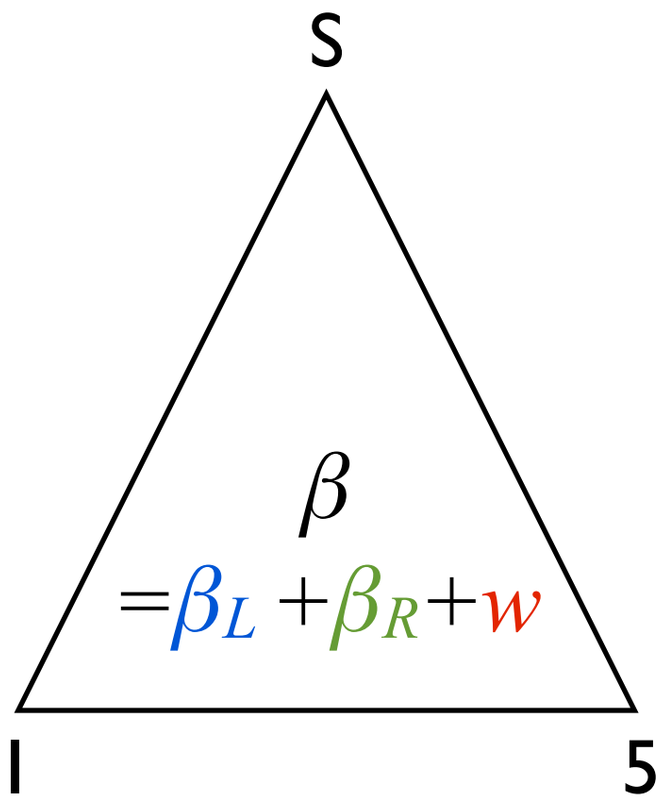

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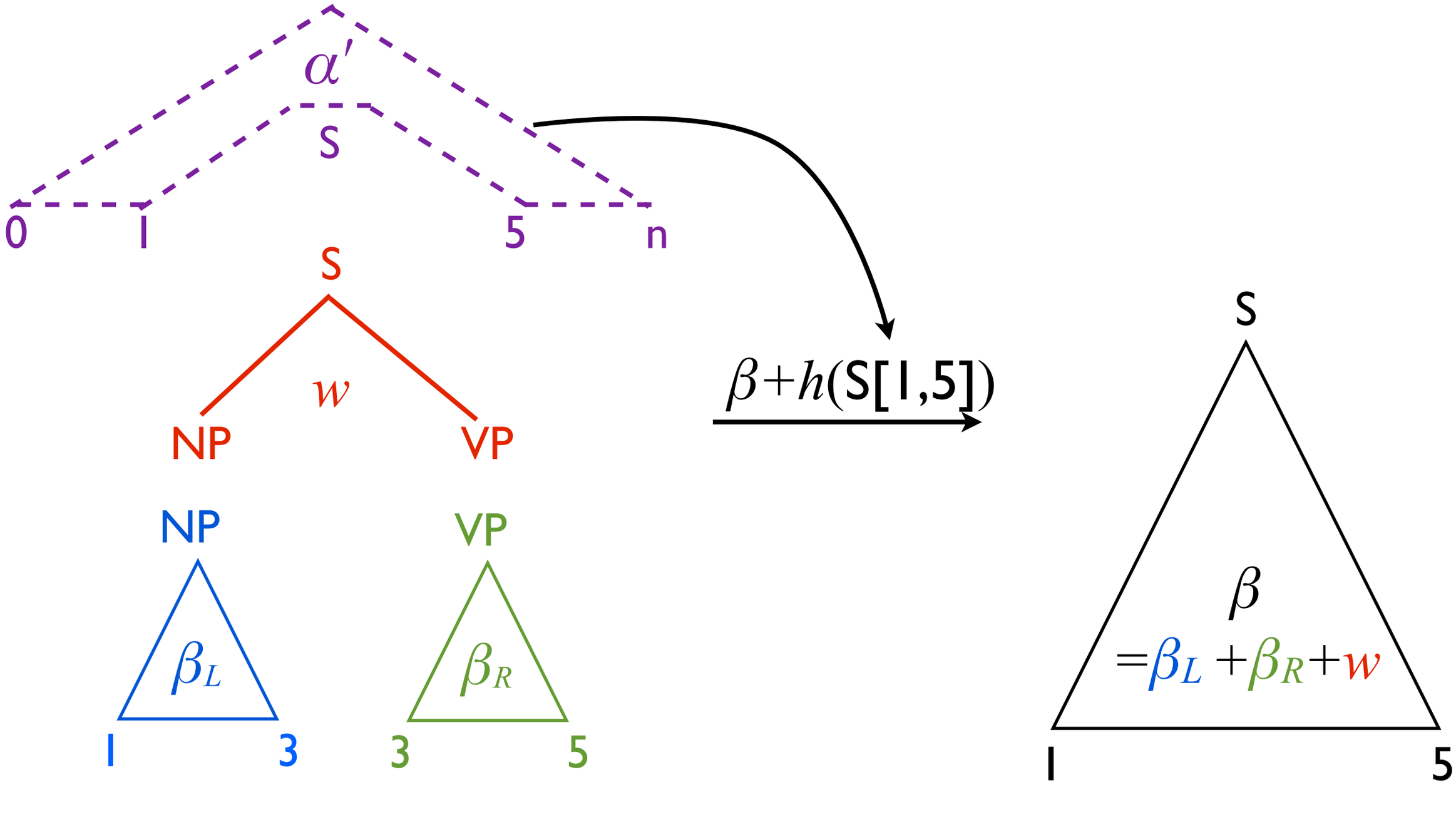

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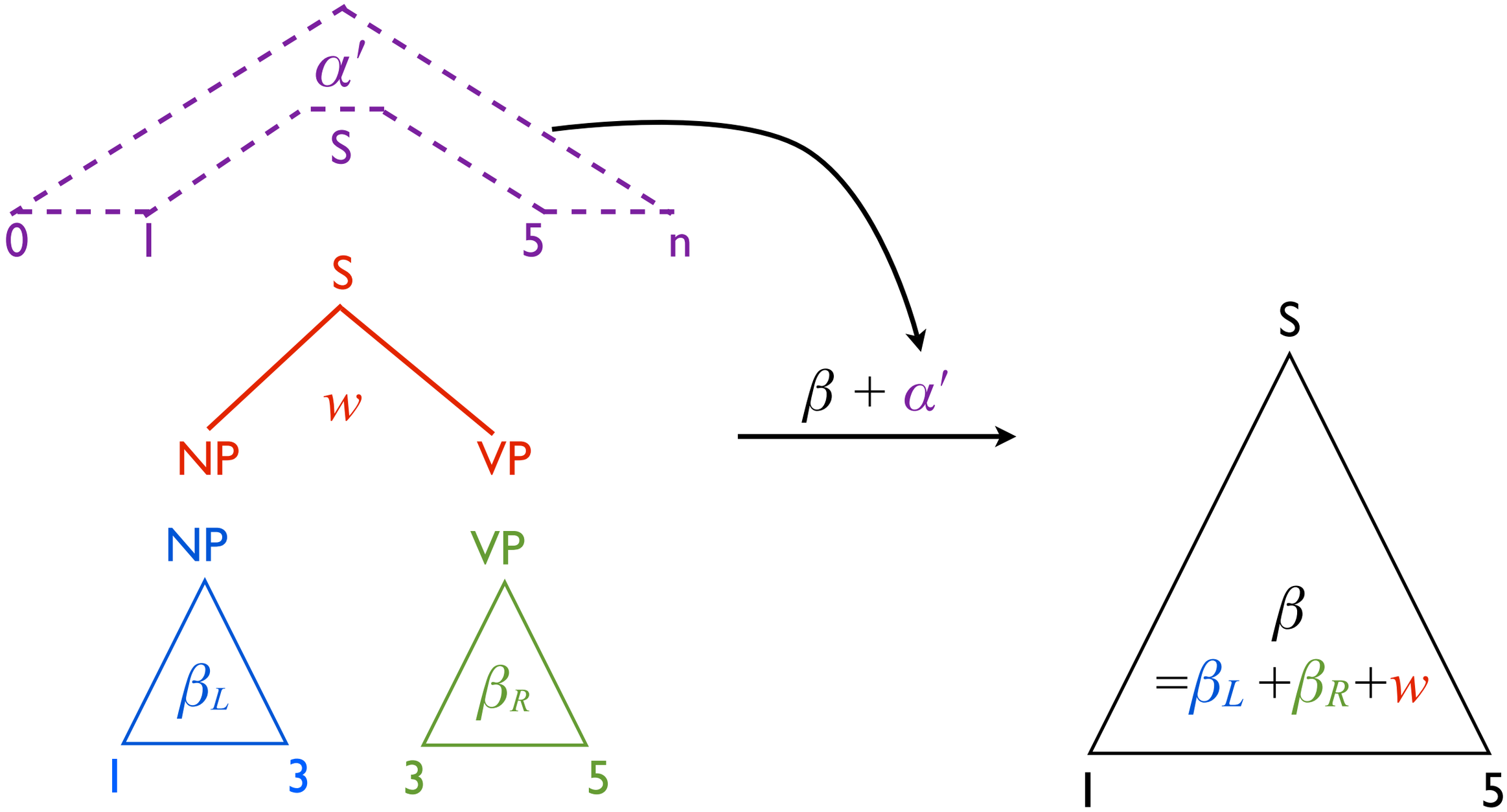

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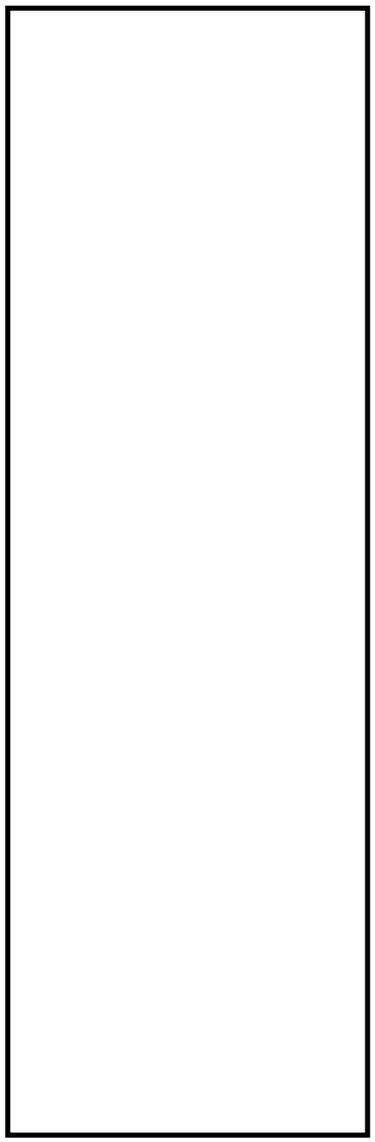

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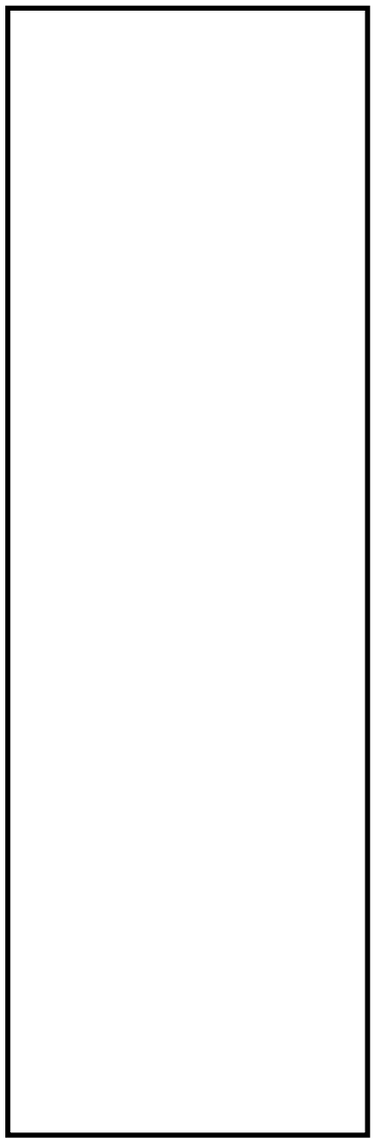

Agenda

Charts

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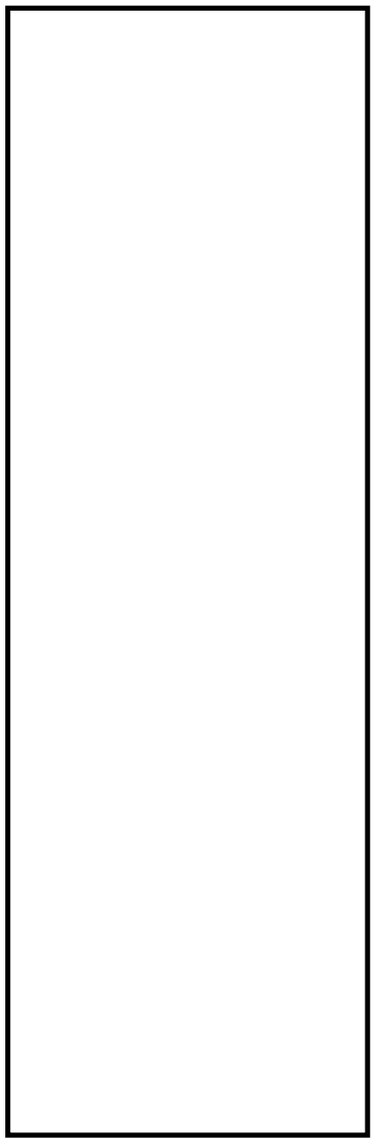
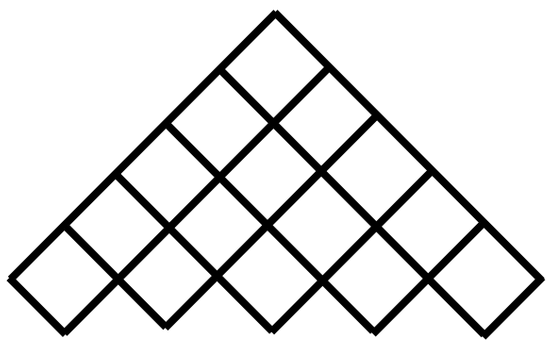
HA*

inside



Agenda

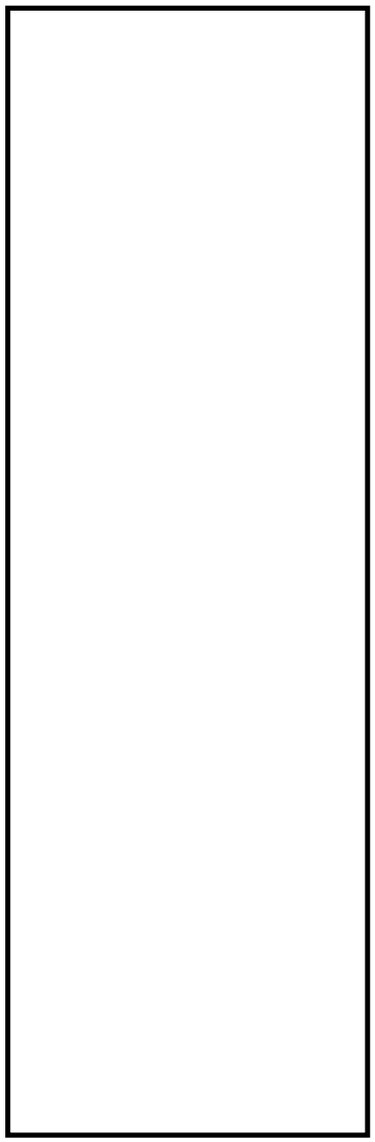


Charts

HA*

inside

outside



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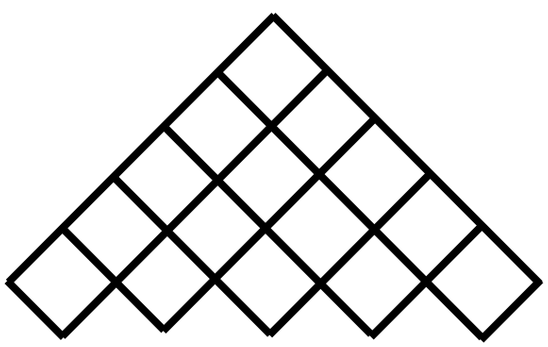

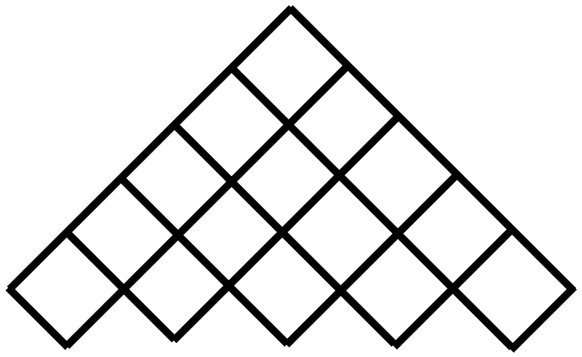

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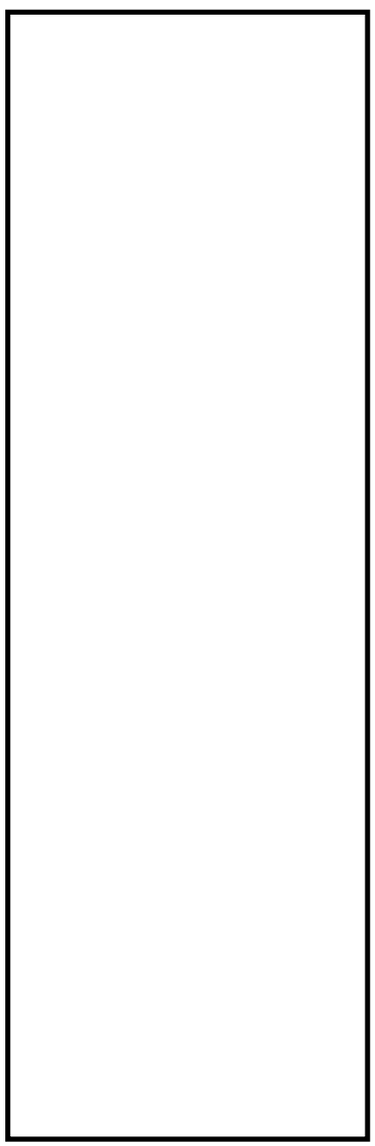

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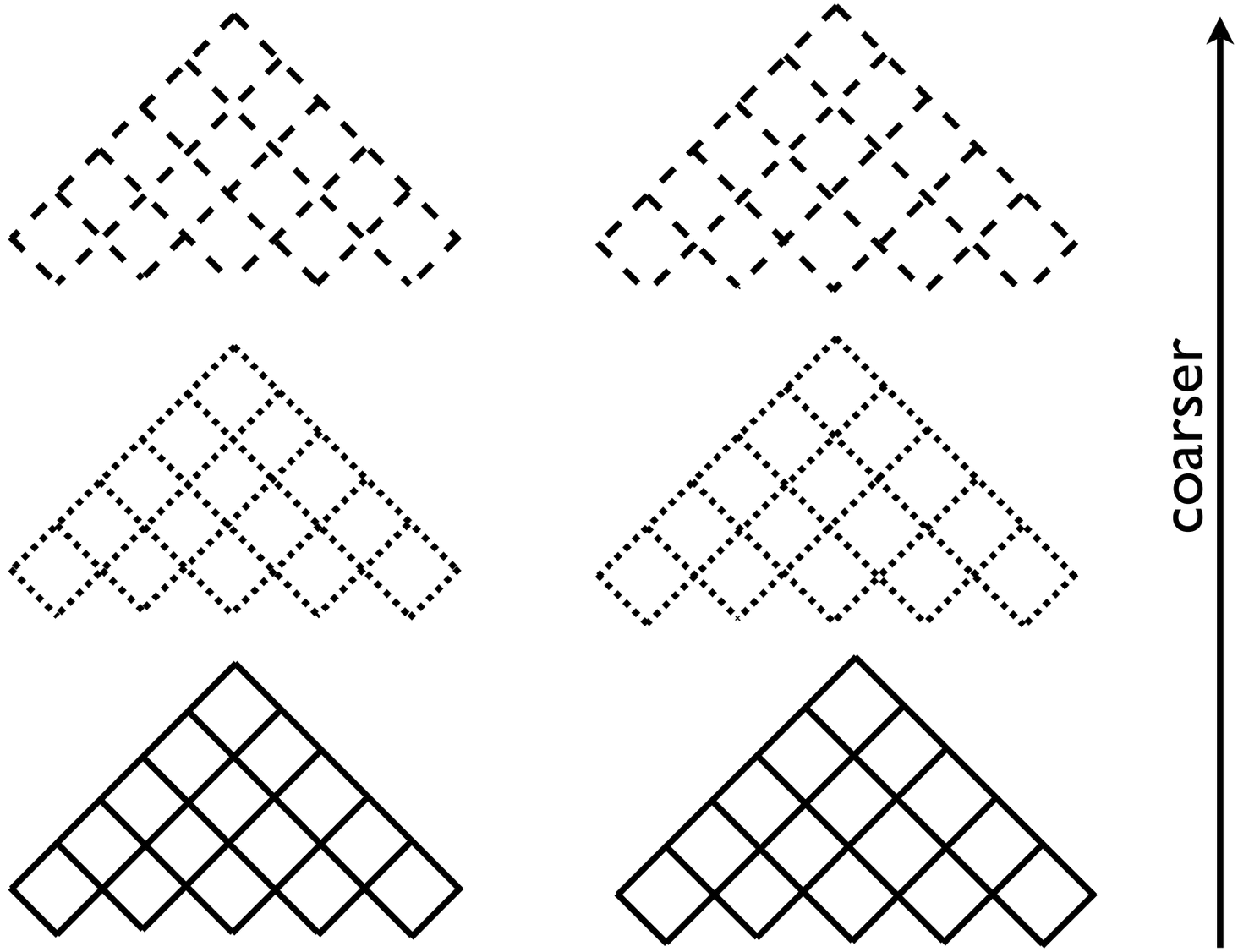

coarser

Charts

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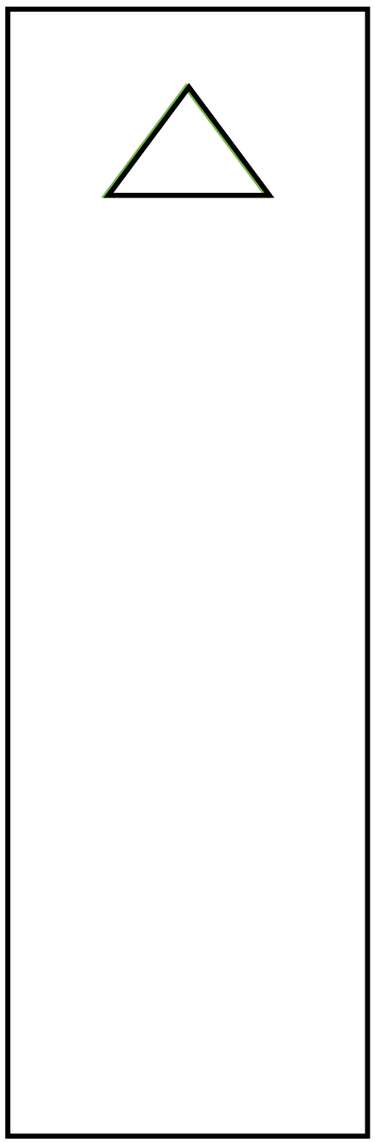

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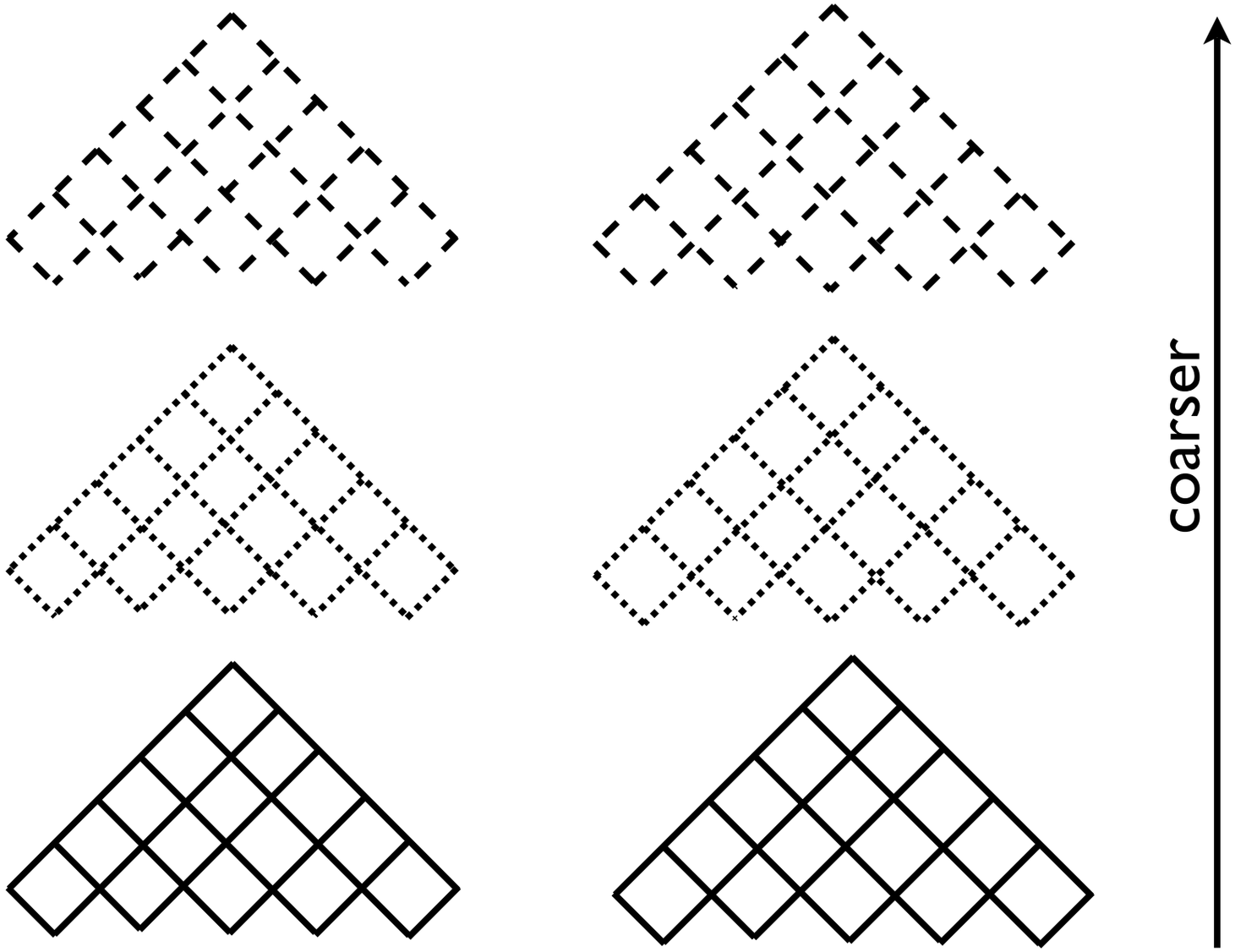

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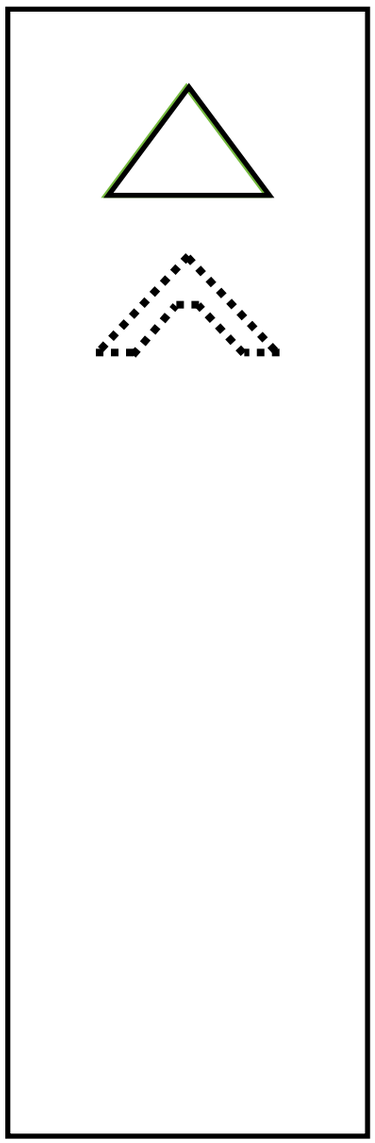

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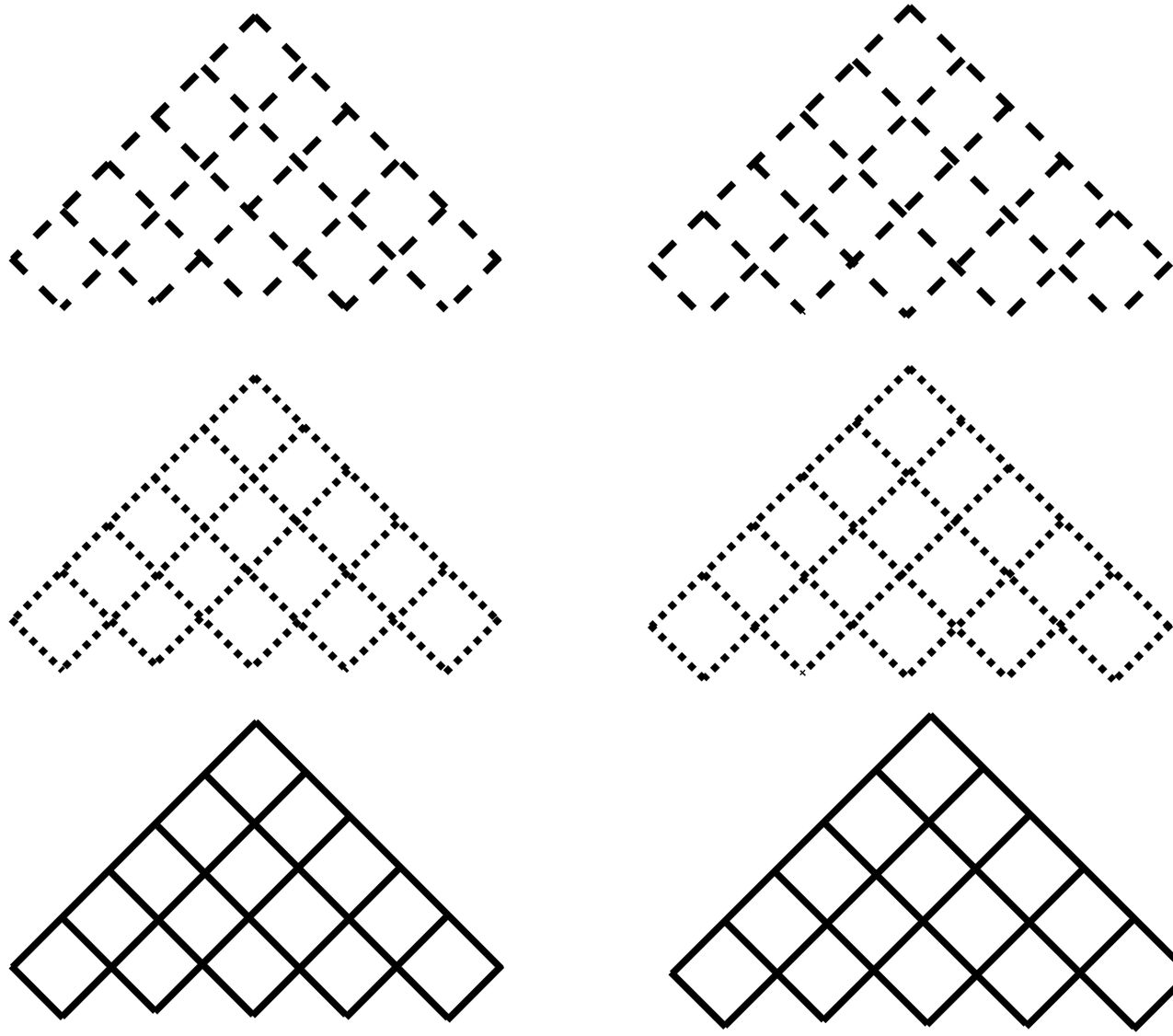

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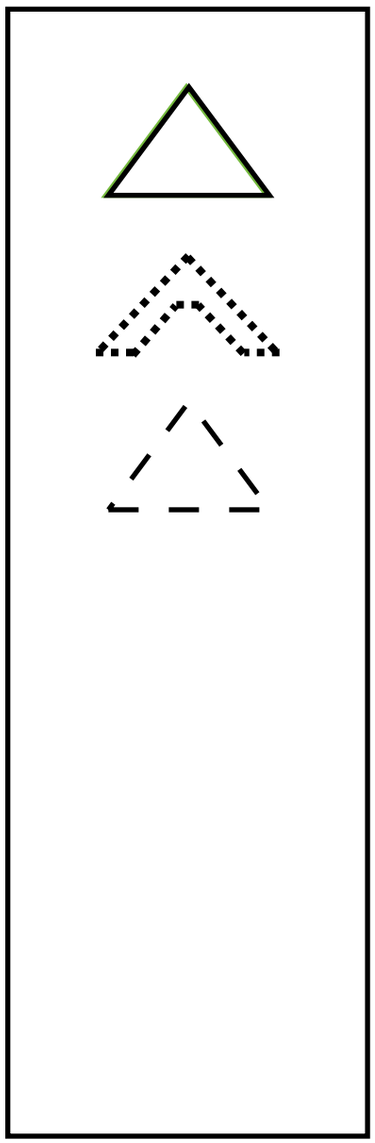

Agenda

inside

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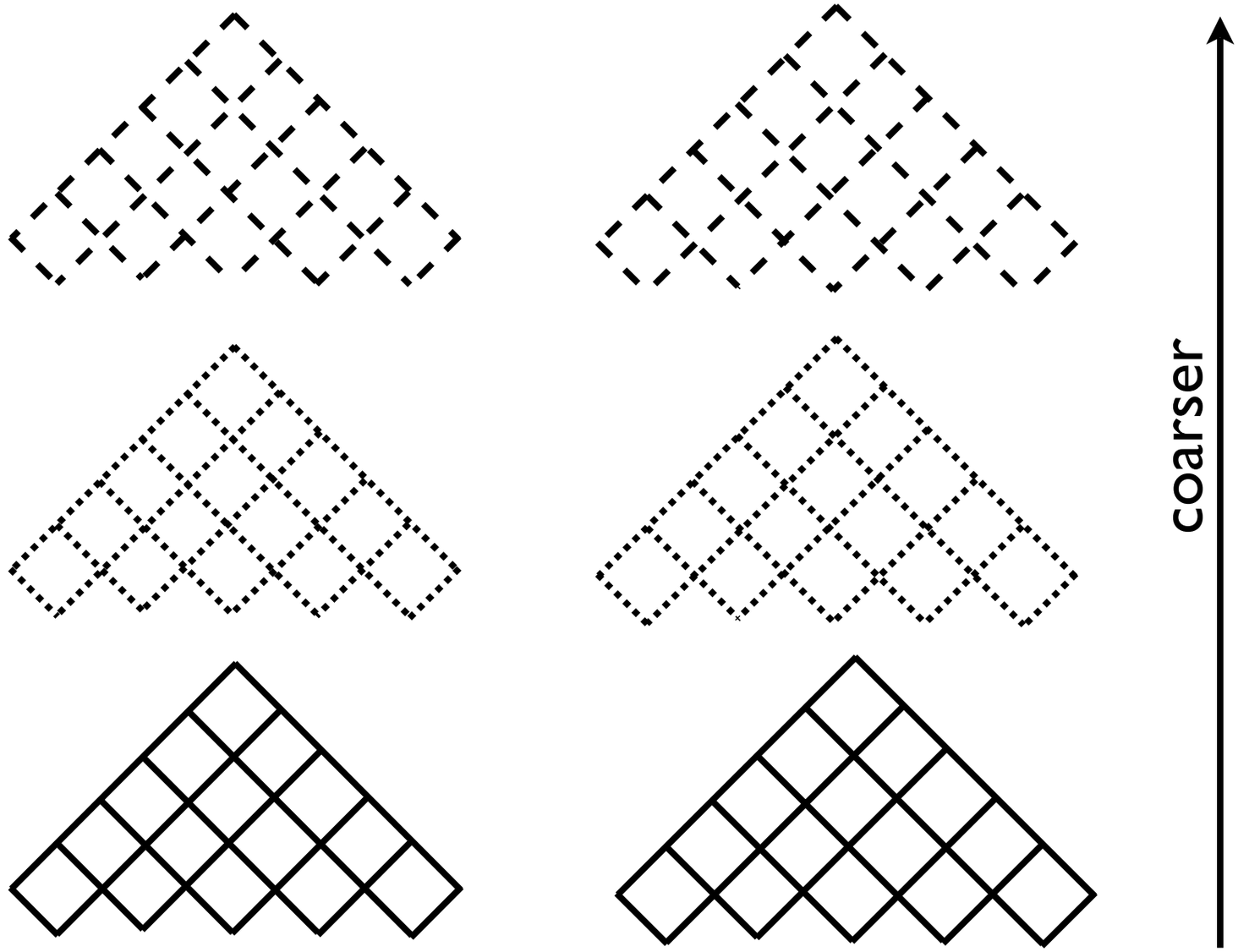

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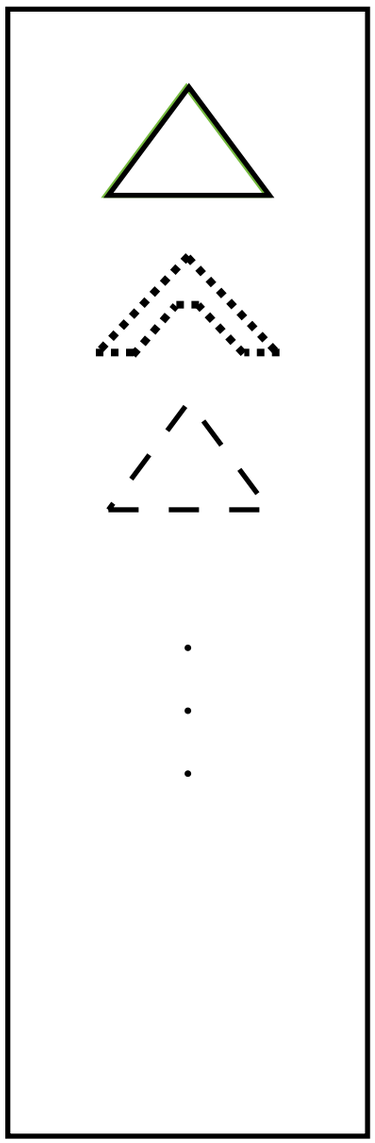

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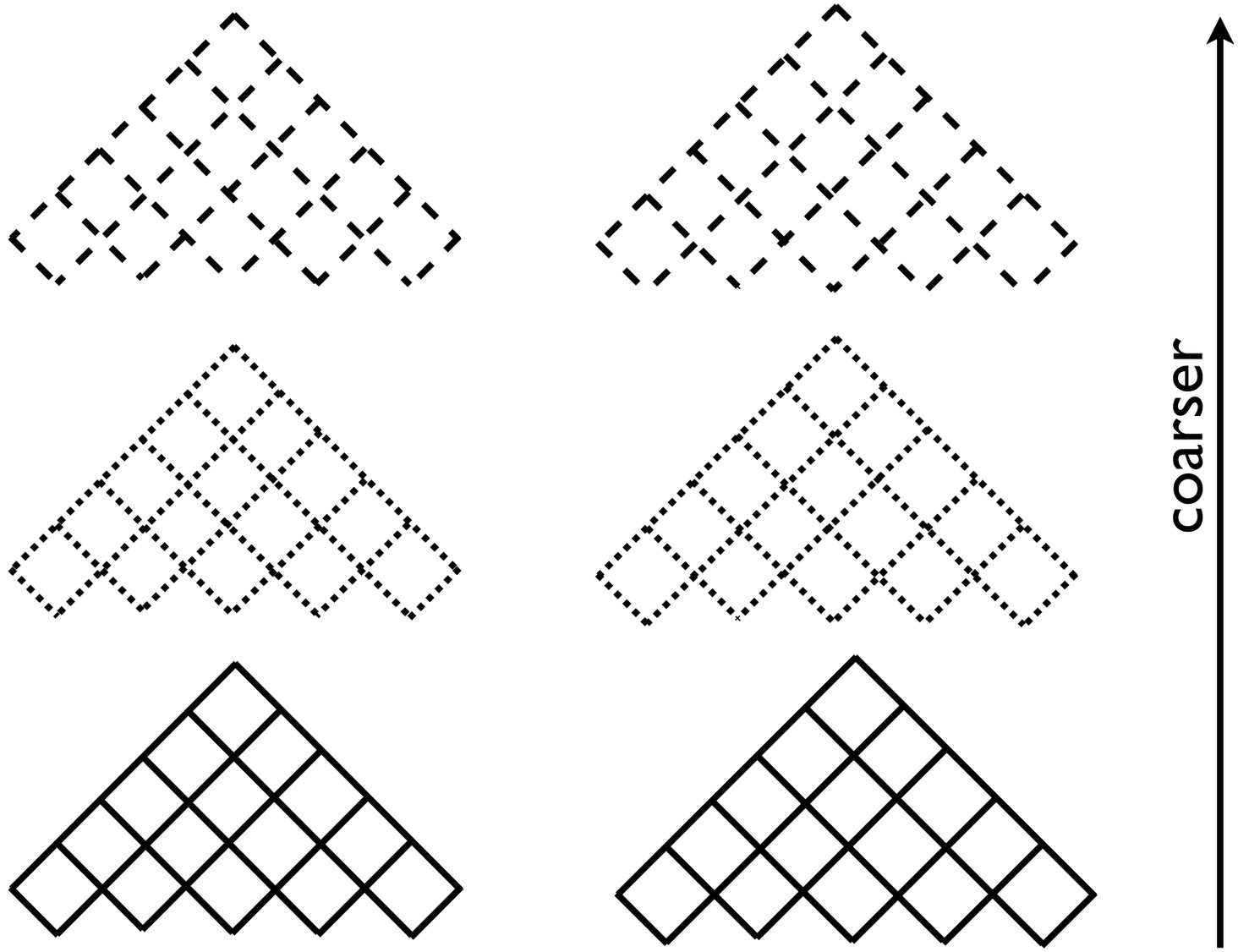

Charts

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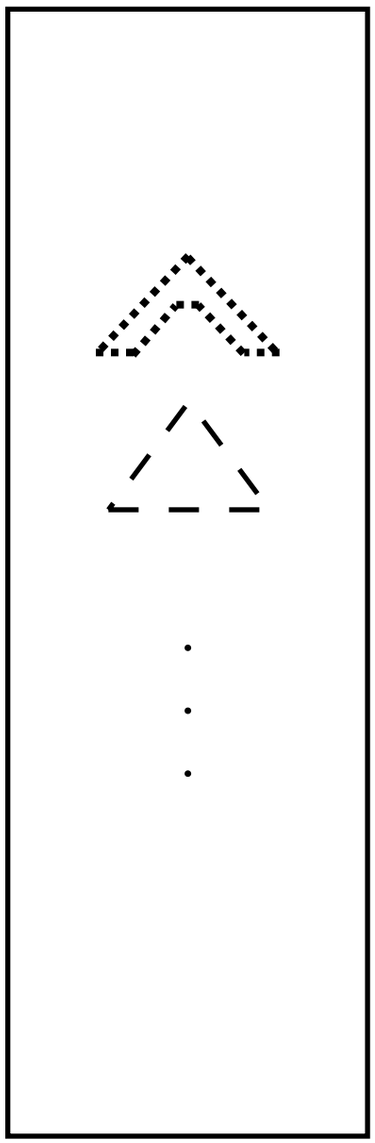
Berkeley

HA*



Agenda

inside

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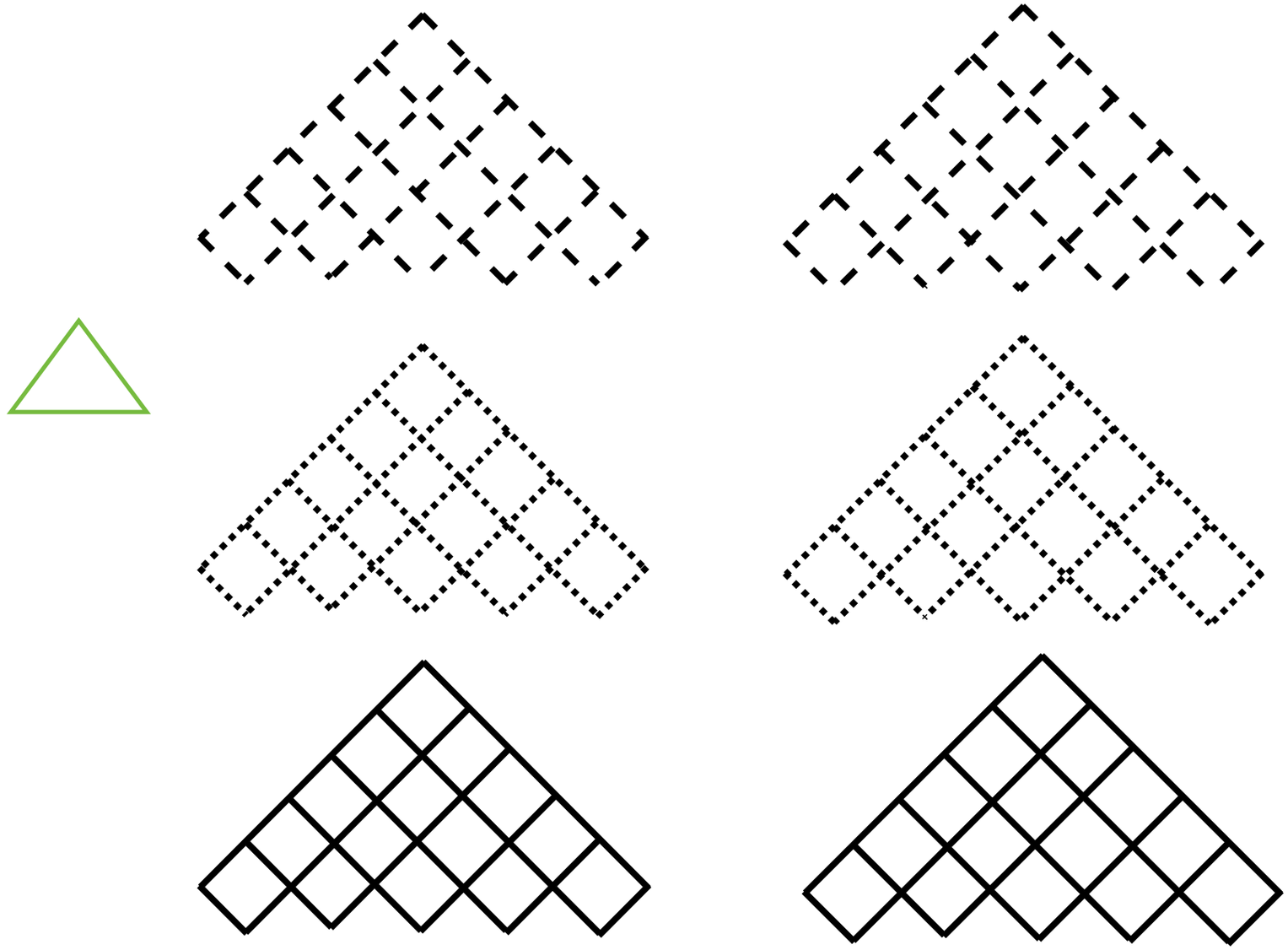

coarser

Charts

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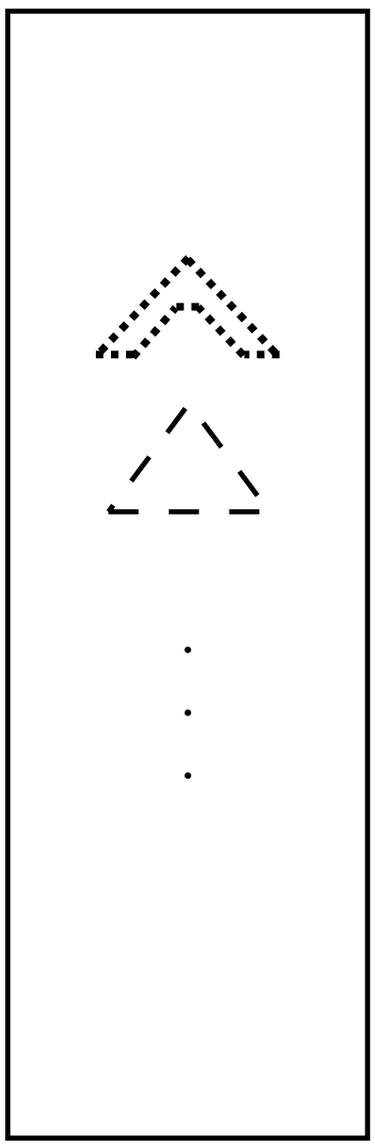

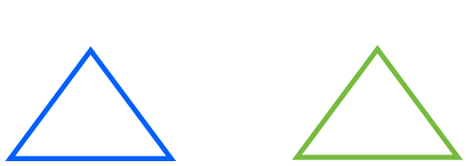

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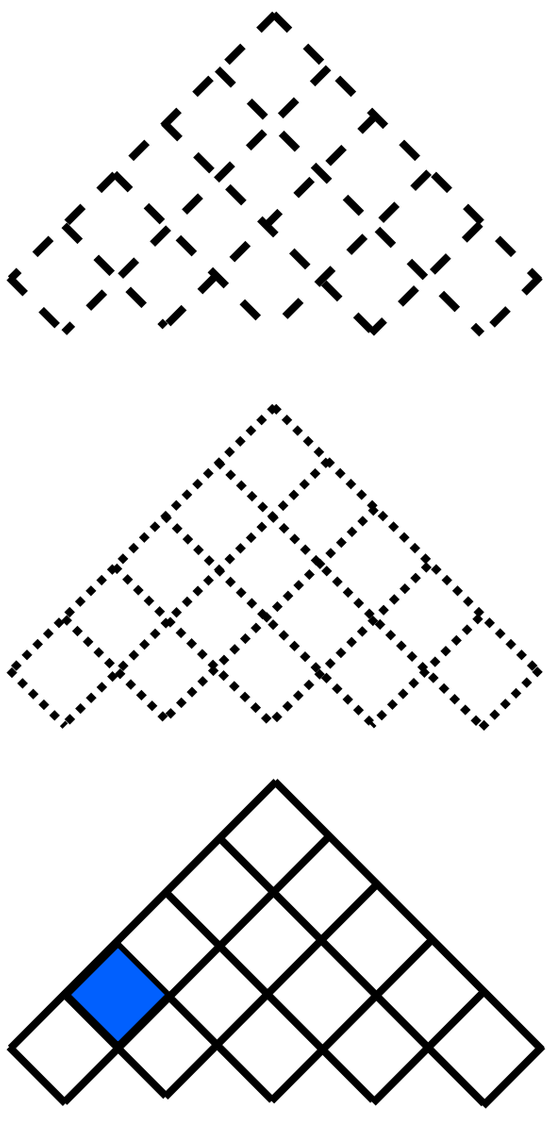

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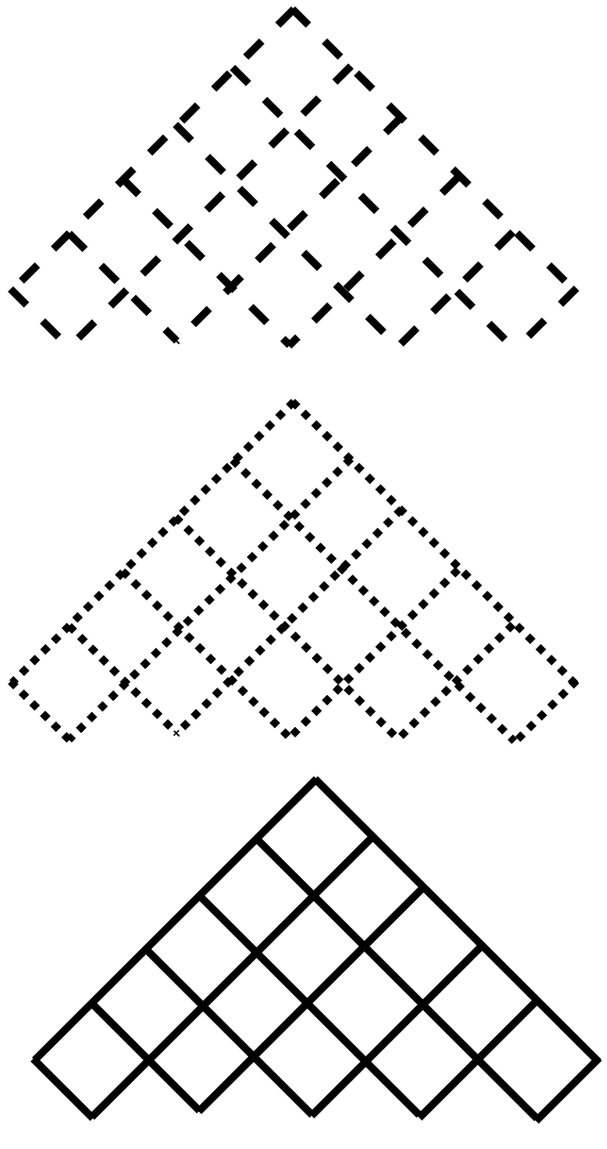

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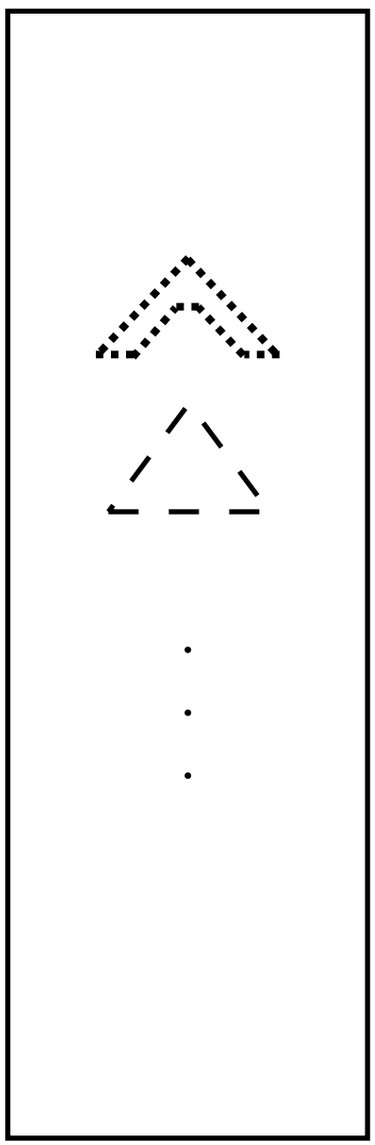
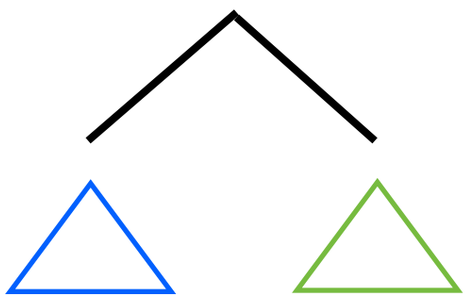


Agenda



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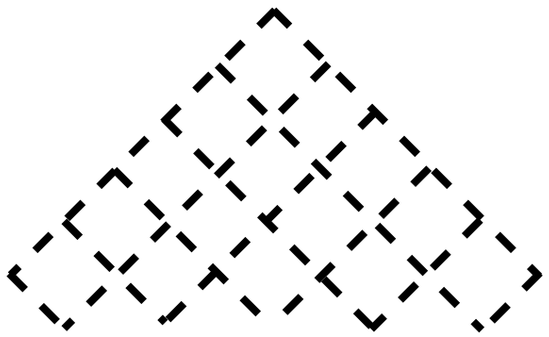

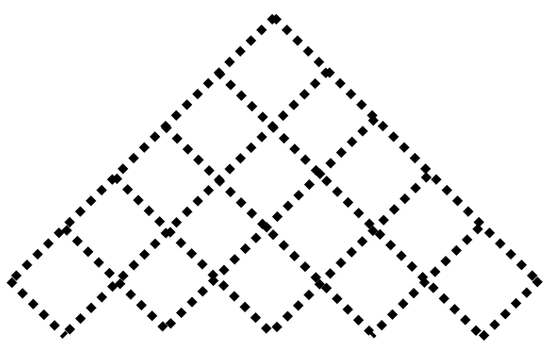

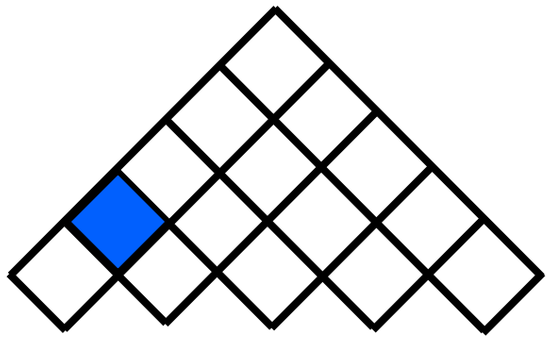

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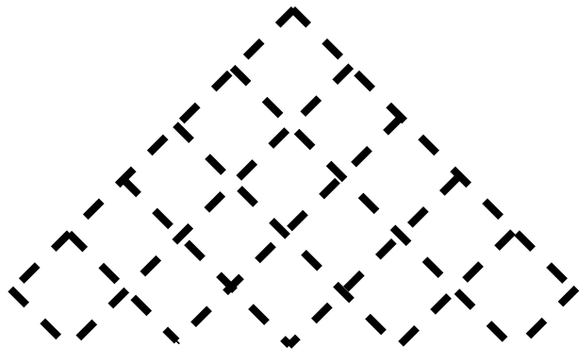

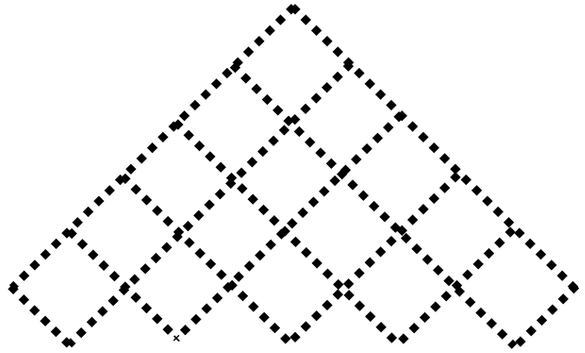

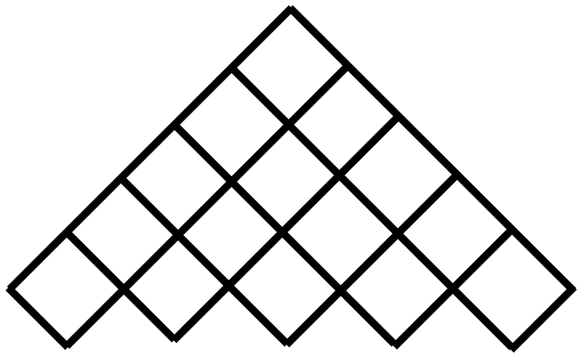

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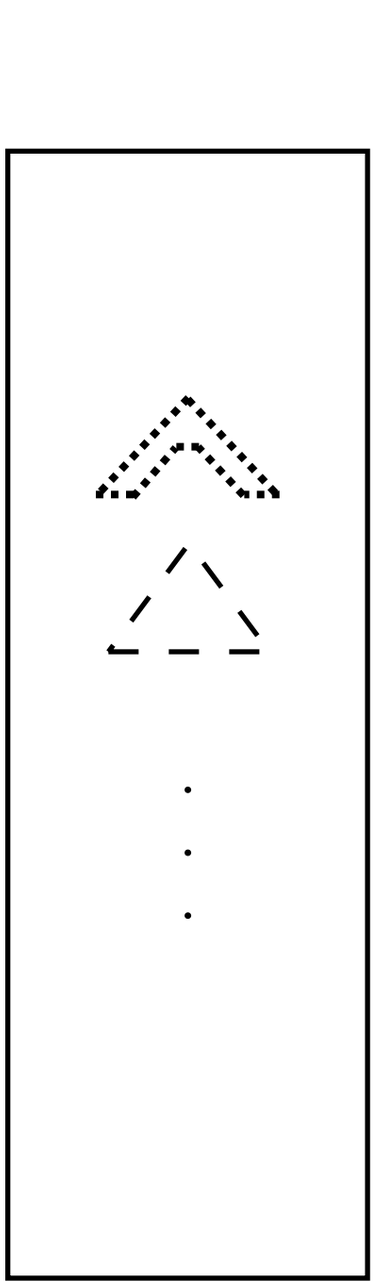

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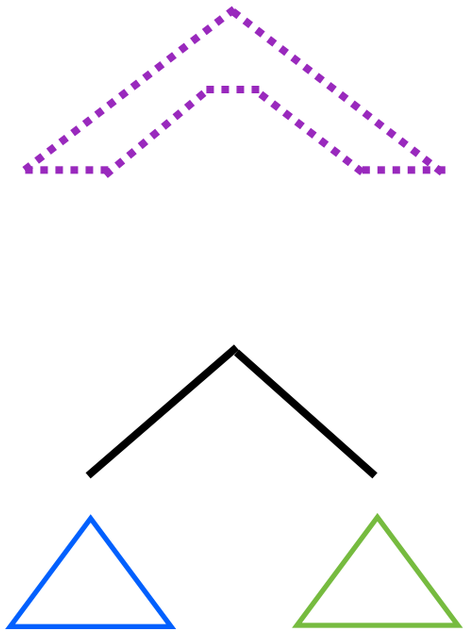

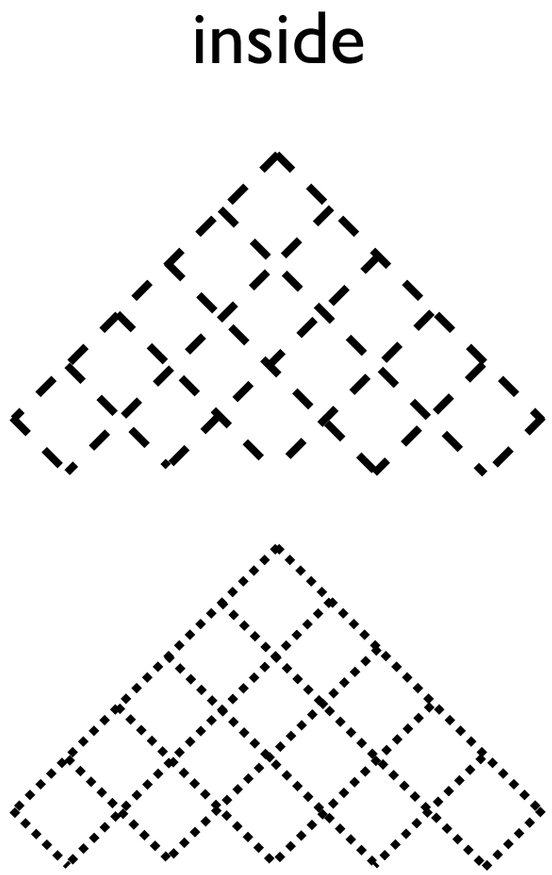

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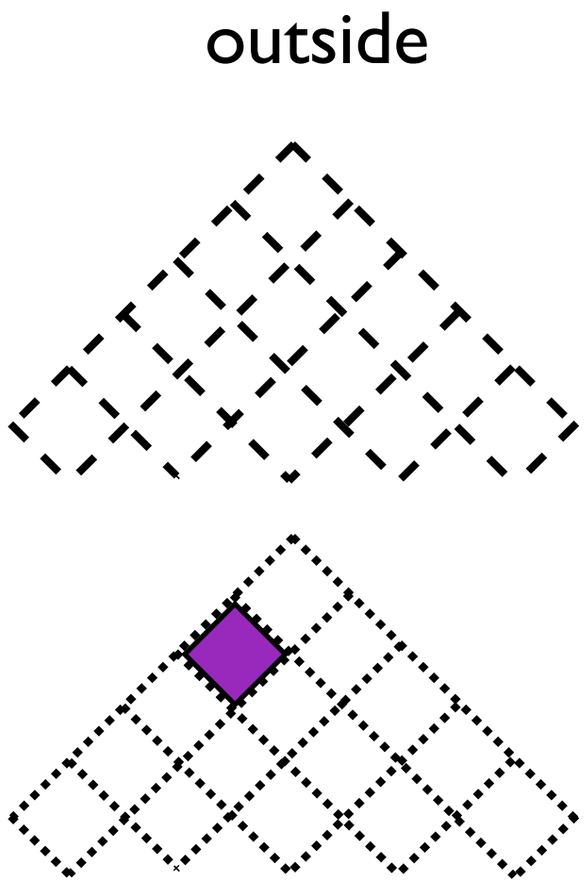

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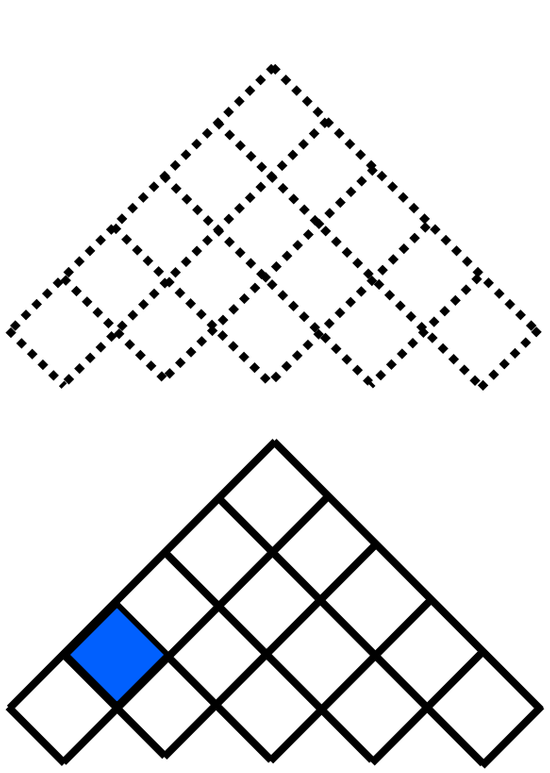

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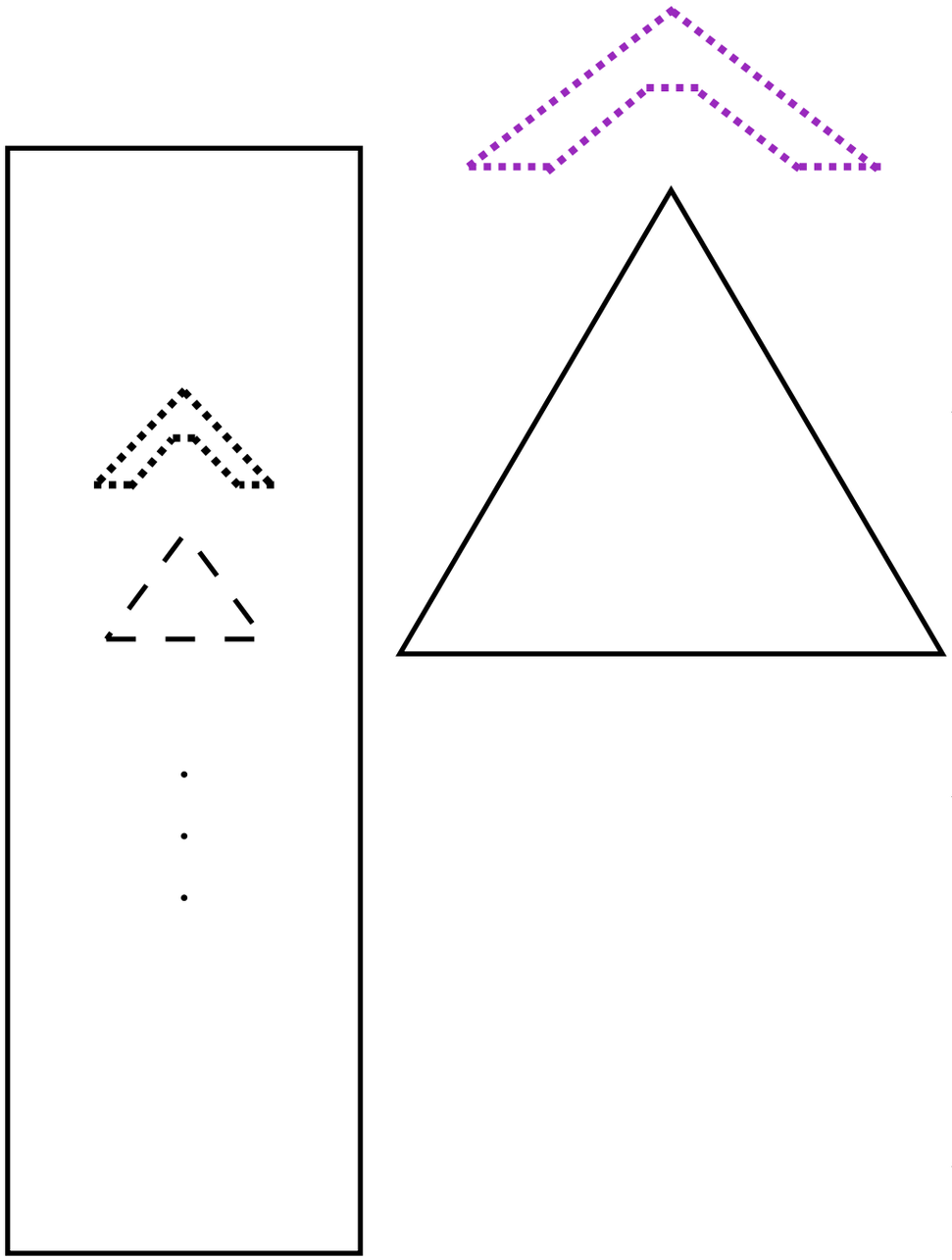

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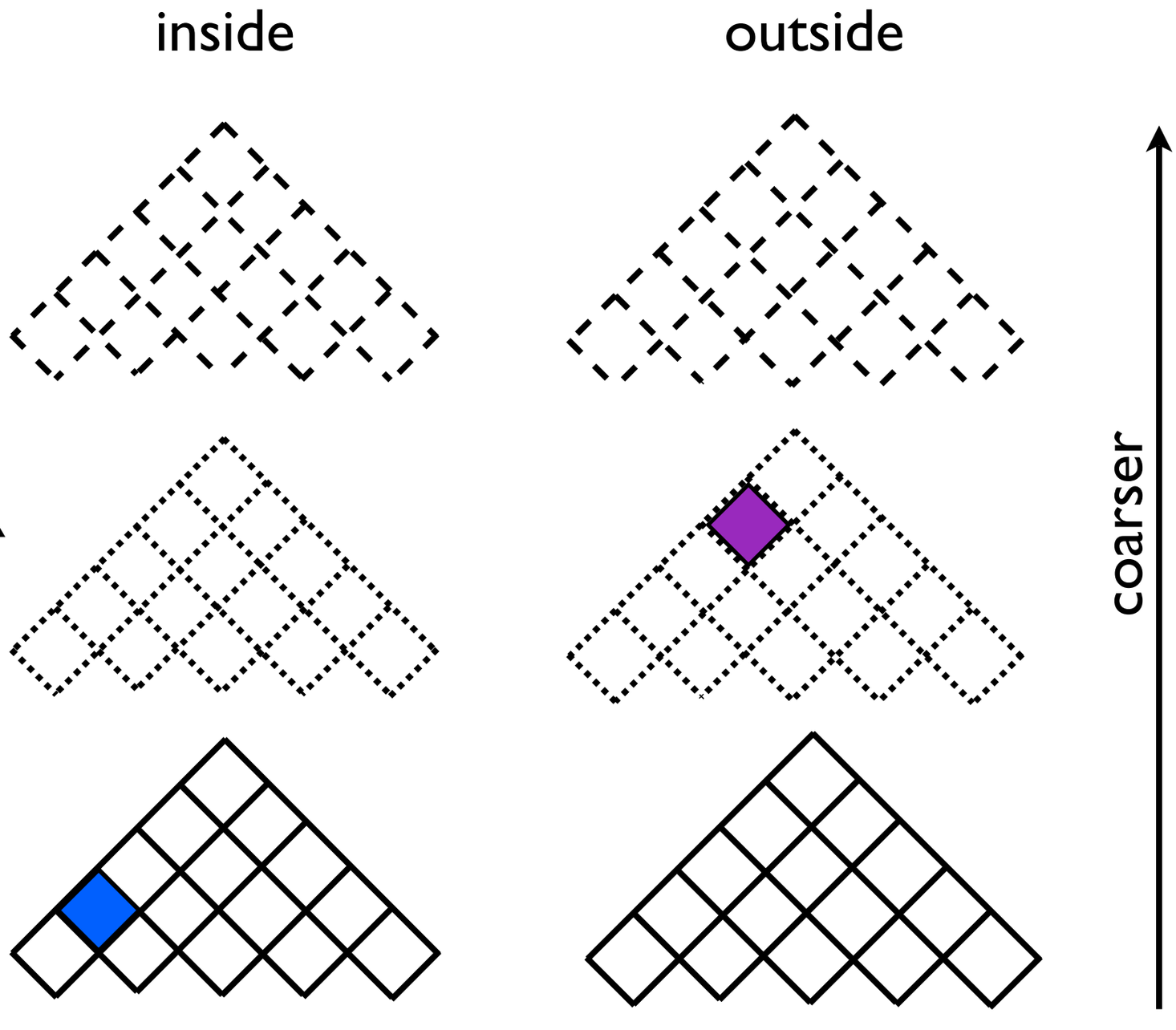

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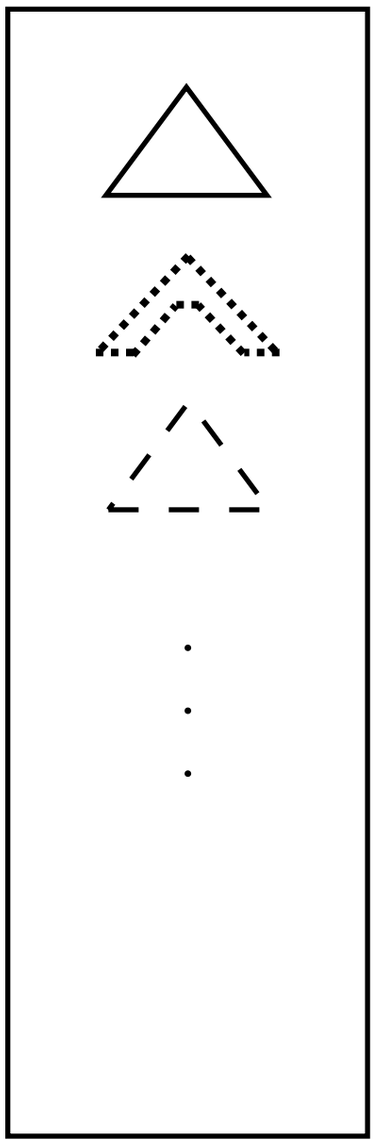

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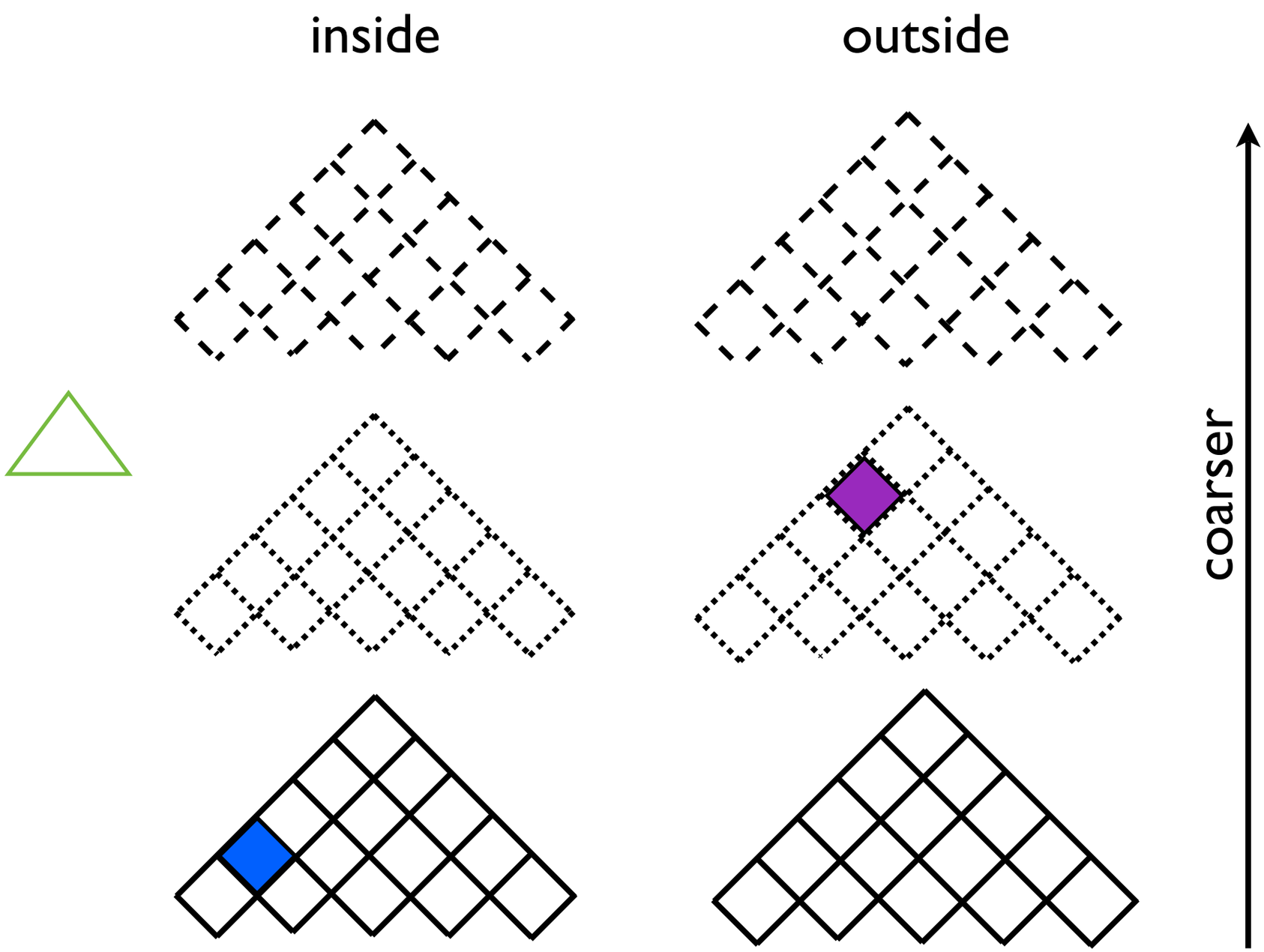

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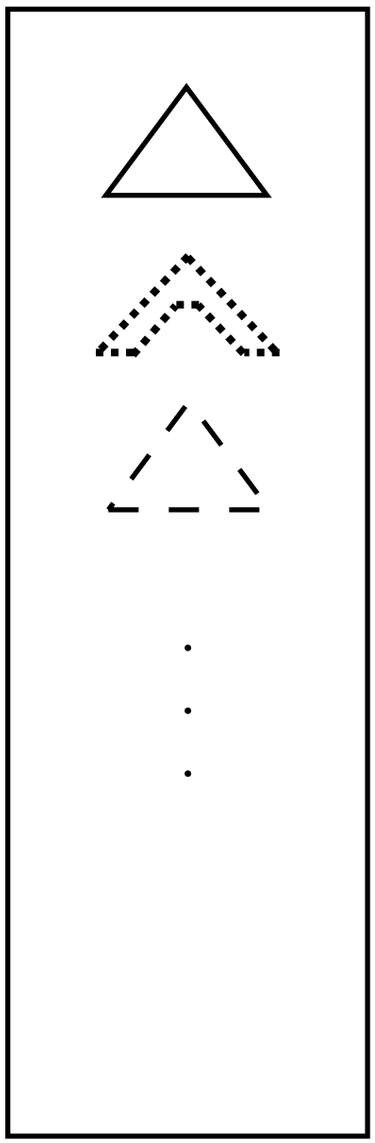
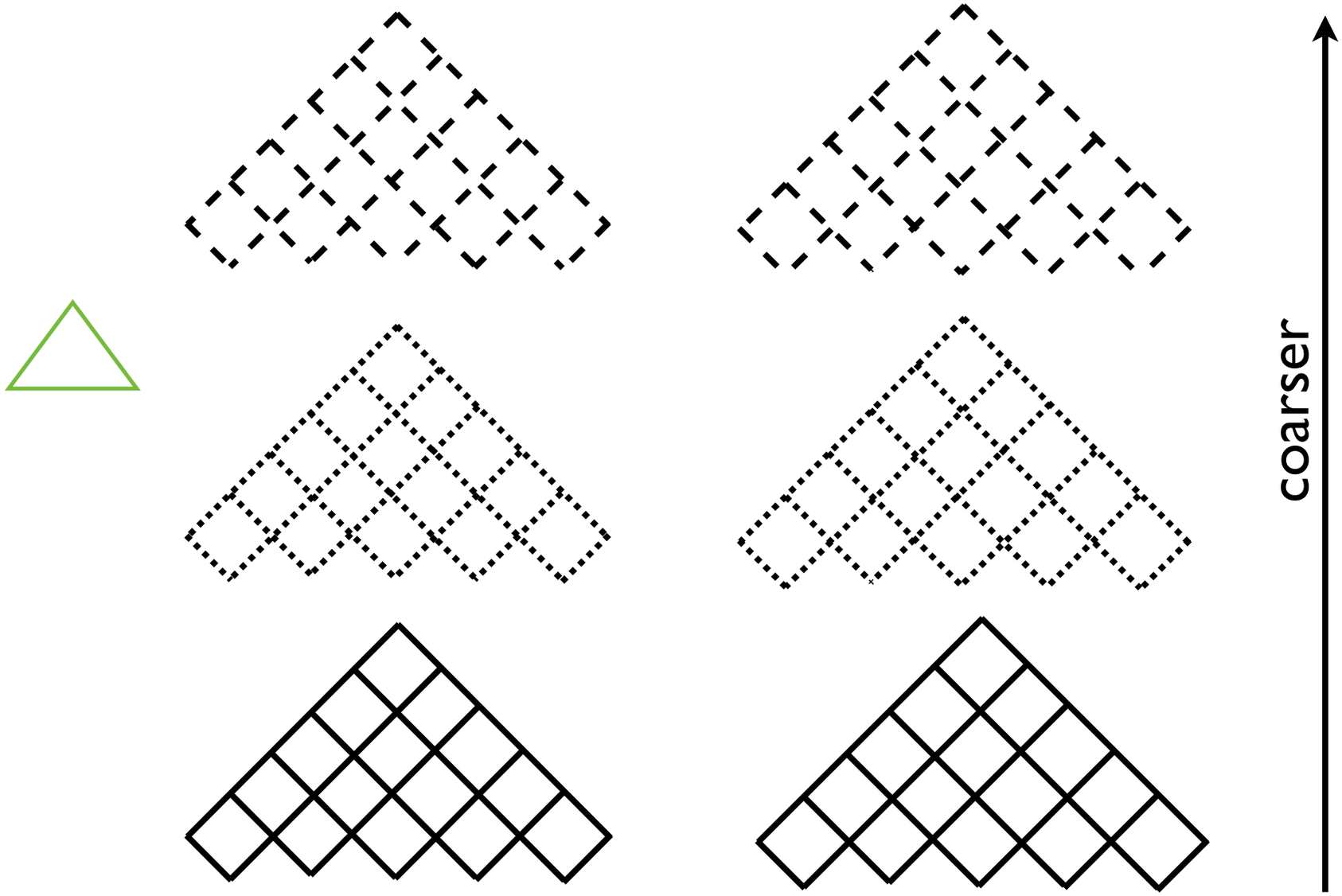


Agenda

inside

outside



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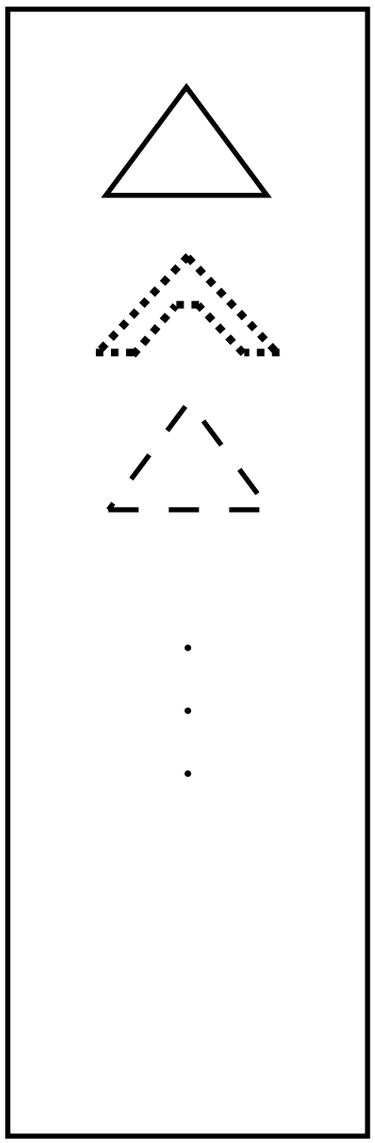

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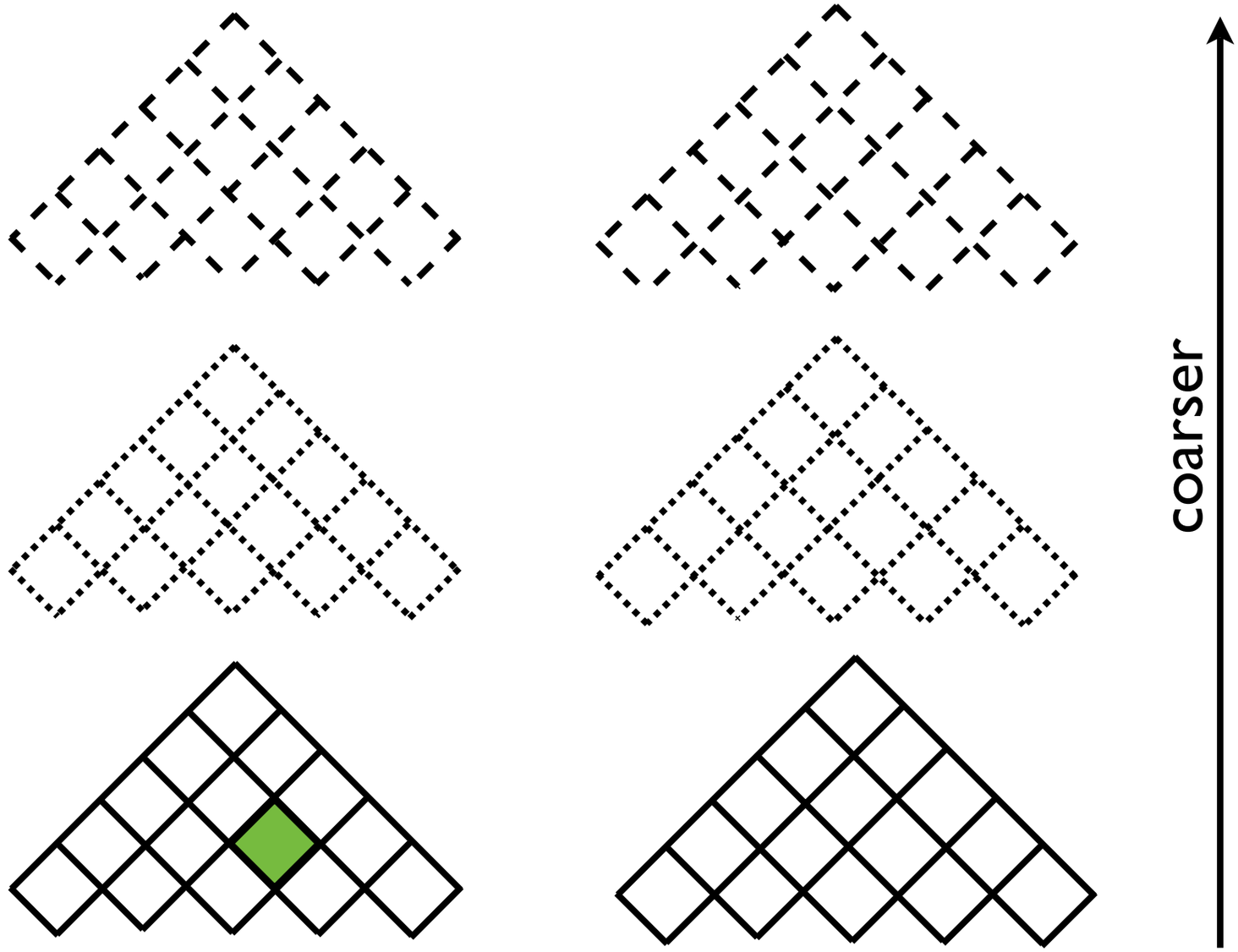

Charts

Coarse-to-Fine

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

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- We use Viterbi posteriors for pruning (Petrov and Klein 2007)

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

- This reformulation makes architectures directly comparable

HA* vs. HCTF Qualitatively

HA*	HCTF

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C A L
N L P
Berkeley

HA* vs. HCTF Qualitatively

HA*

- optimal

HCTF

- makes search errors

HA* vs. HCTF Qualitatively

HA*

- optimal
- uses coarse grammars to prioritize search

HCTF

- makes search errors
- uses coarse grammars to prune search

HA* vs. HCTF Qualitatively

HA*

- optimal
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HCTF

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HA* vs. HCTF Qualitatively

HA*

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- min over rules

HCTF

- makes search errors
- uses coarse grammars to prune search
- speed determined by threshold
- average over rules

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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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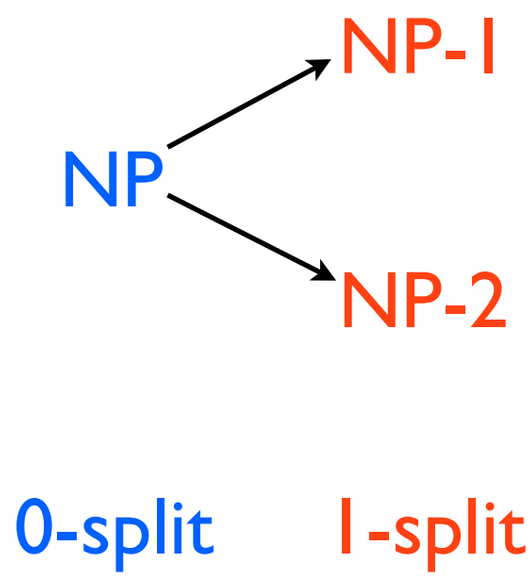

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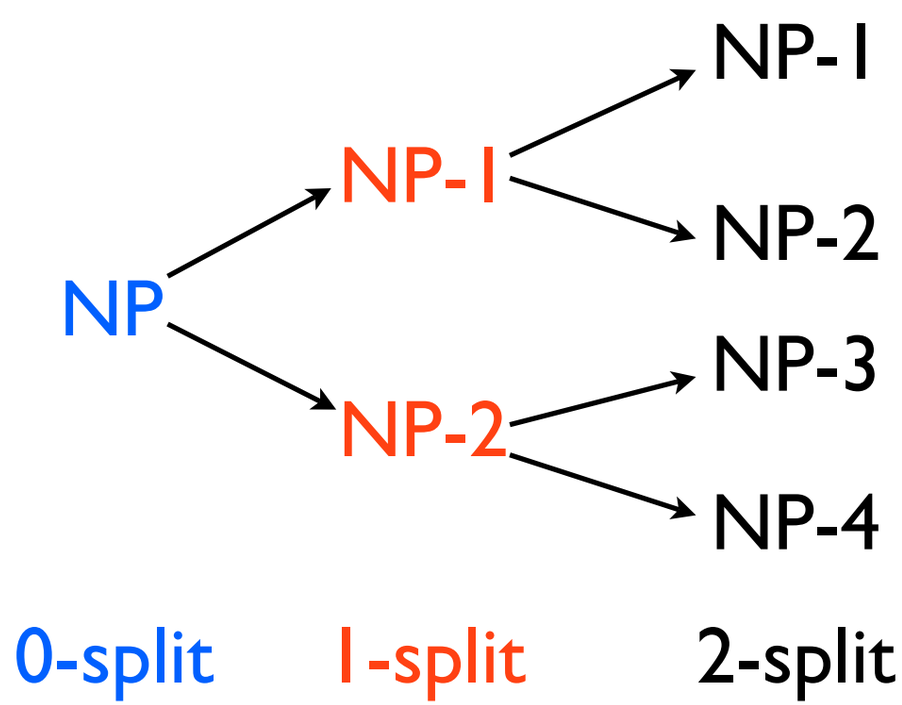

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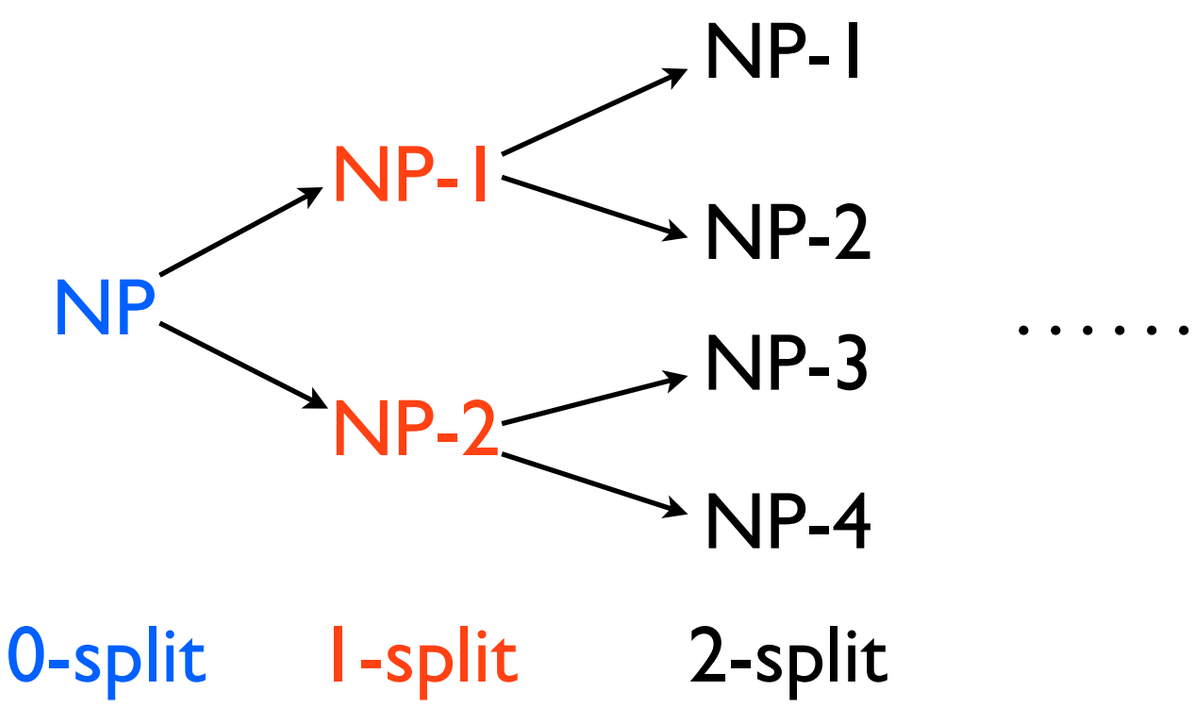
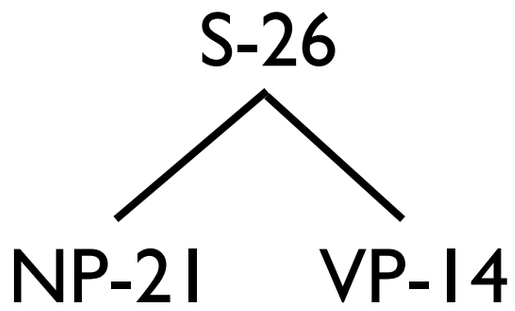
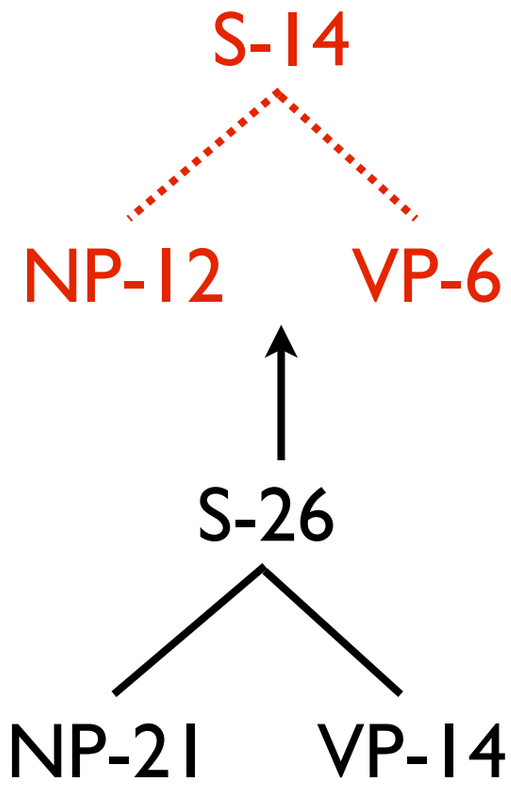


State-Split Projections



6-split

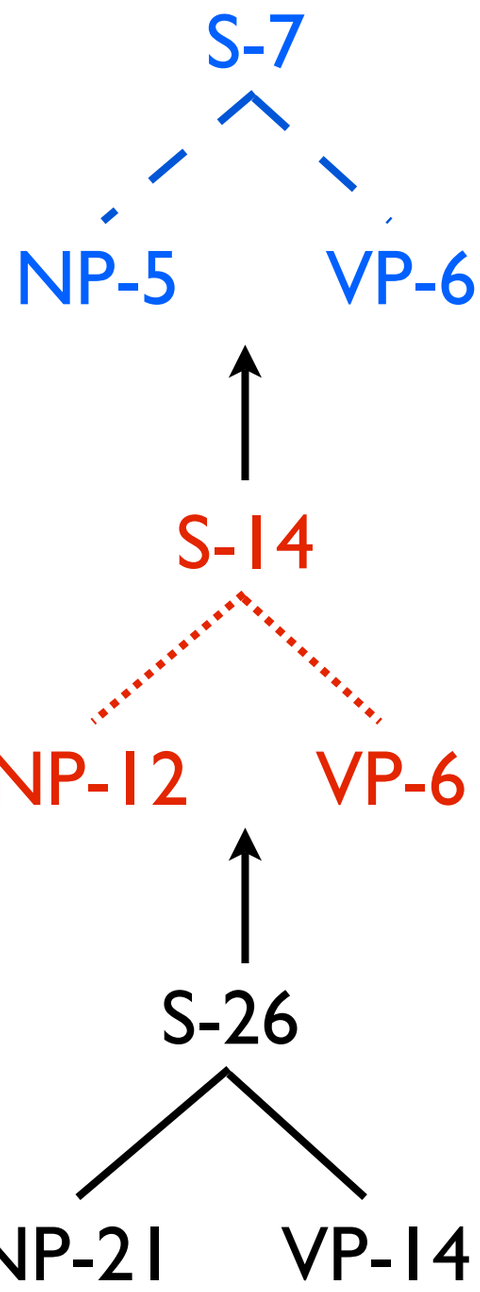
State-Split Projections



5-split

6-split

State-Split Projections

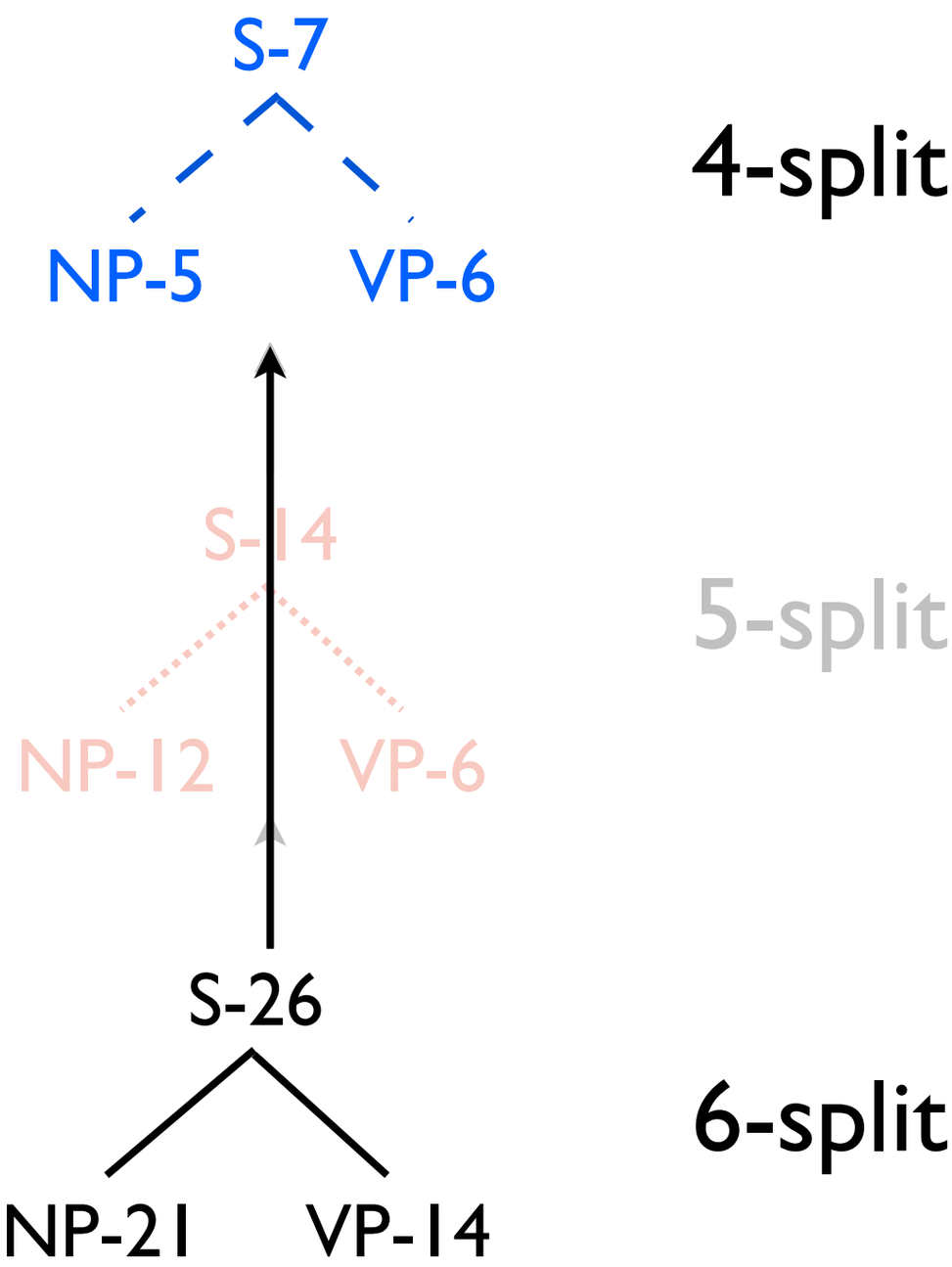


4-split

5-split

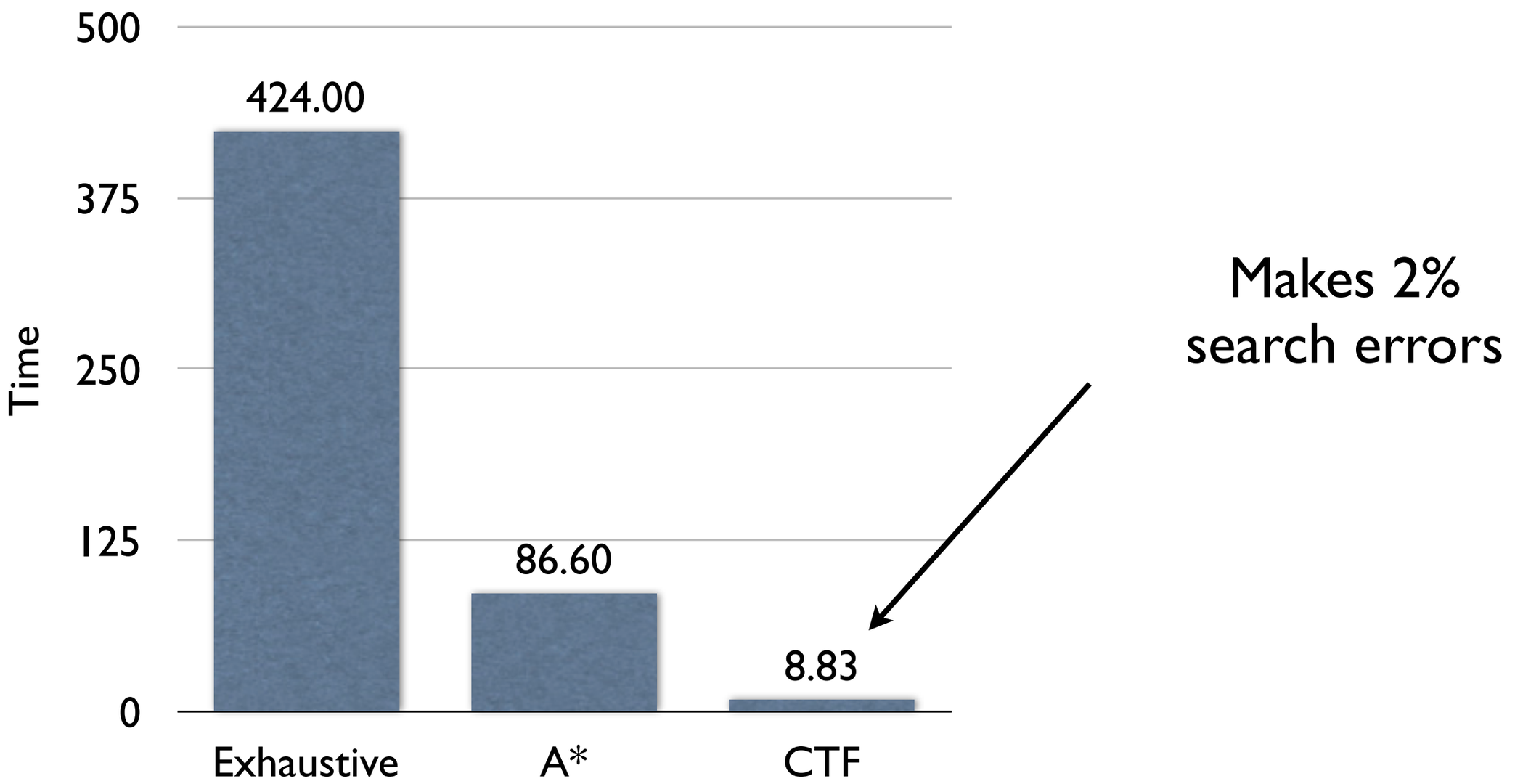
6-split

State-Split Projections



One-Level CTF vs. A*

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



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Hierarchies

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

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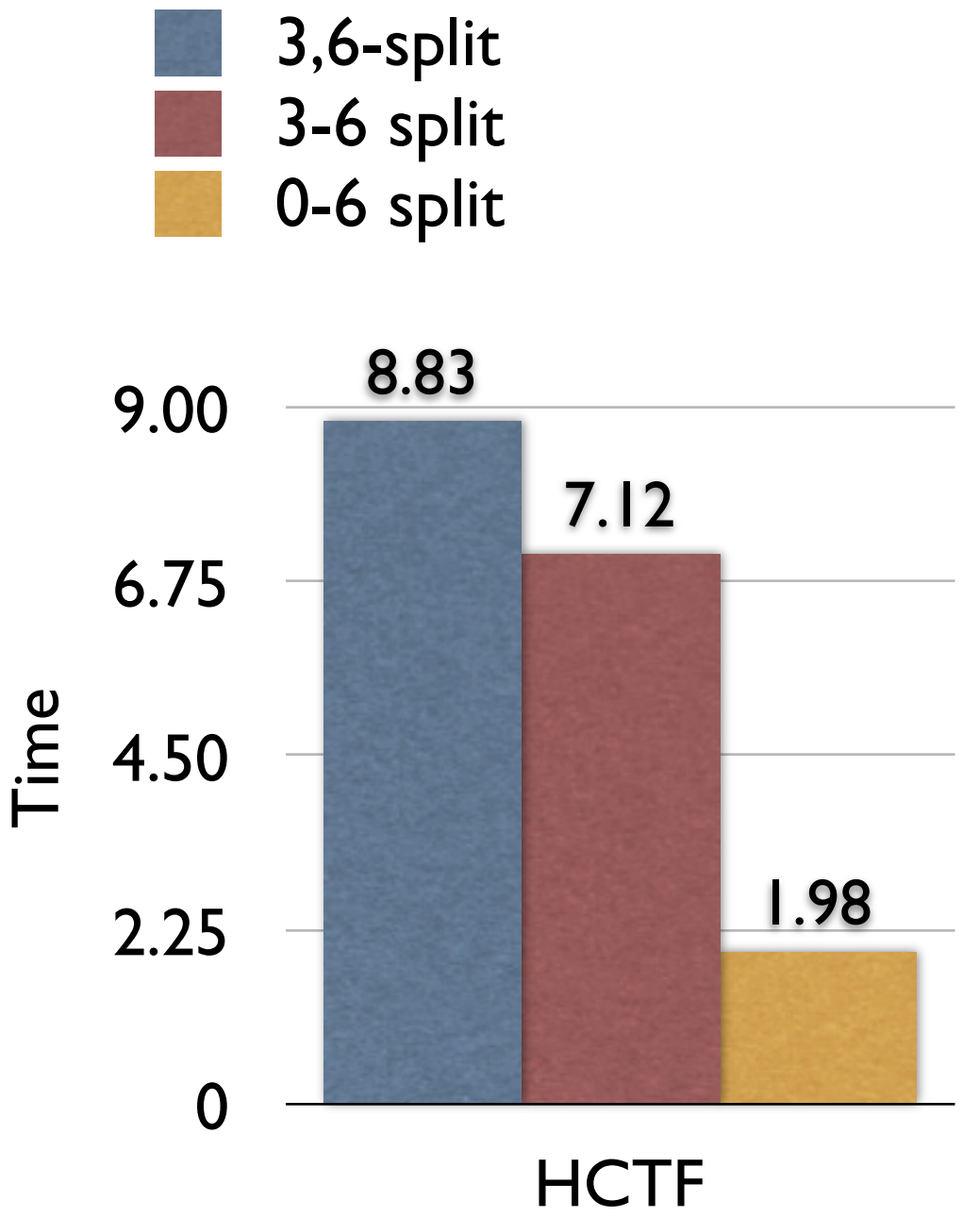
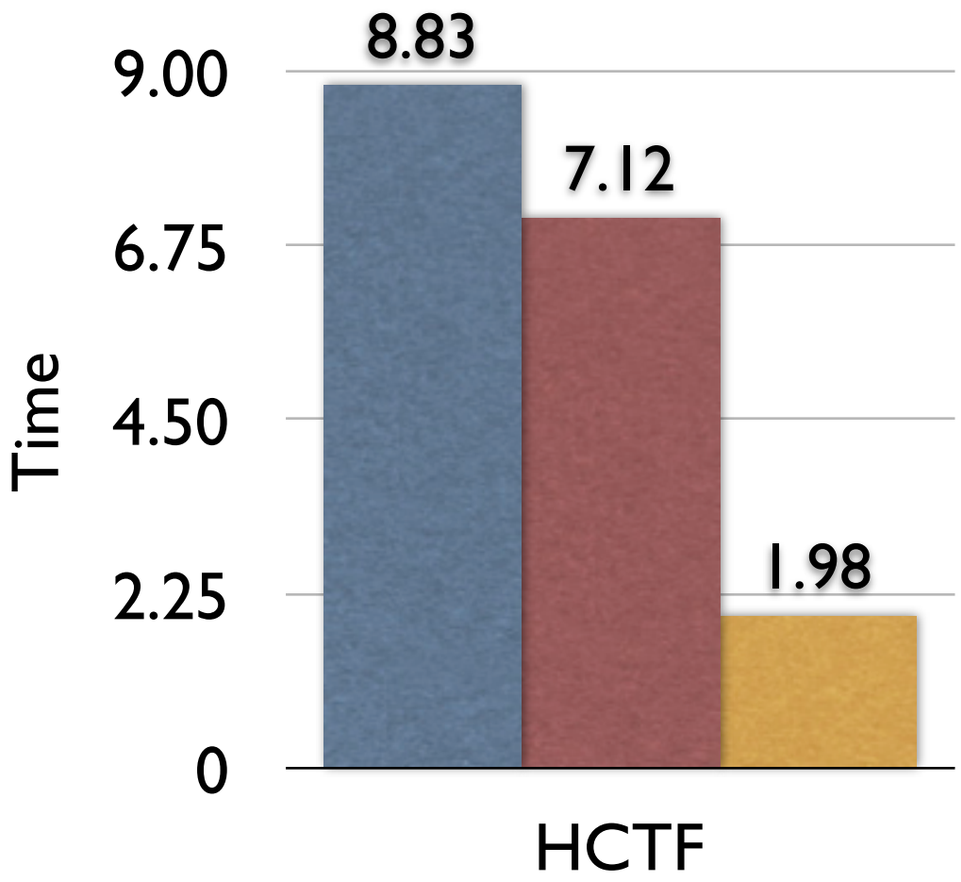
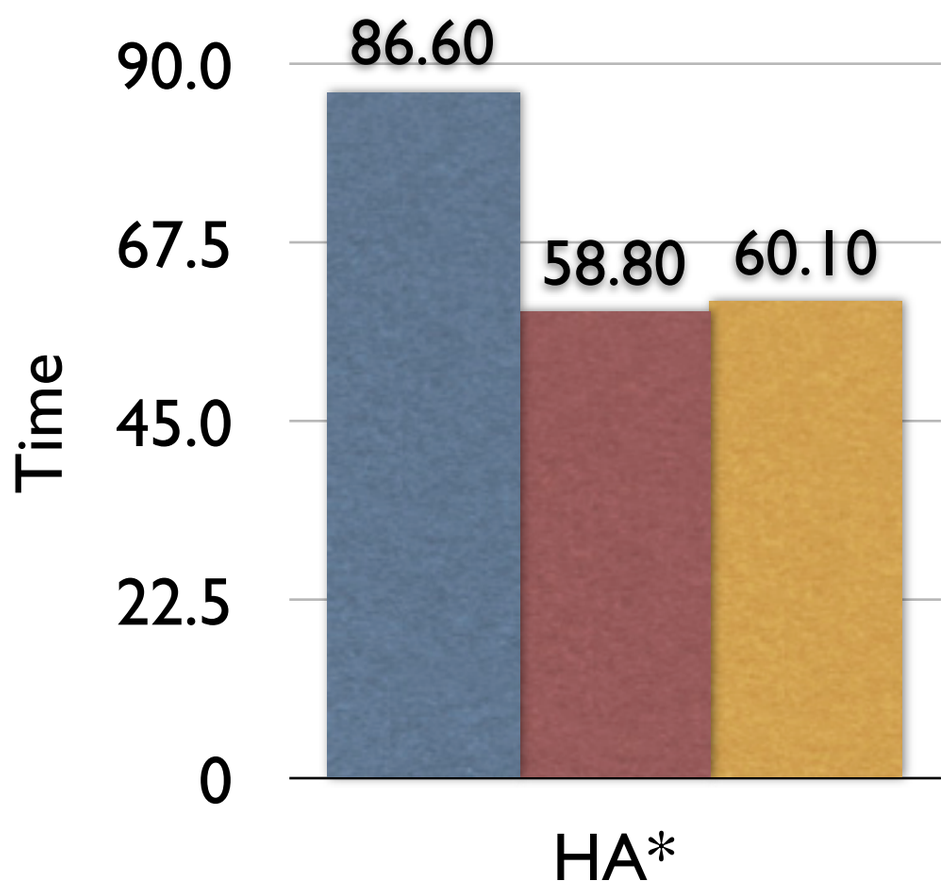


Hierarchies

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

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





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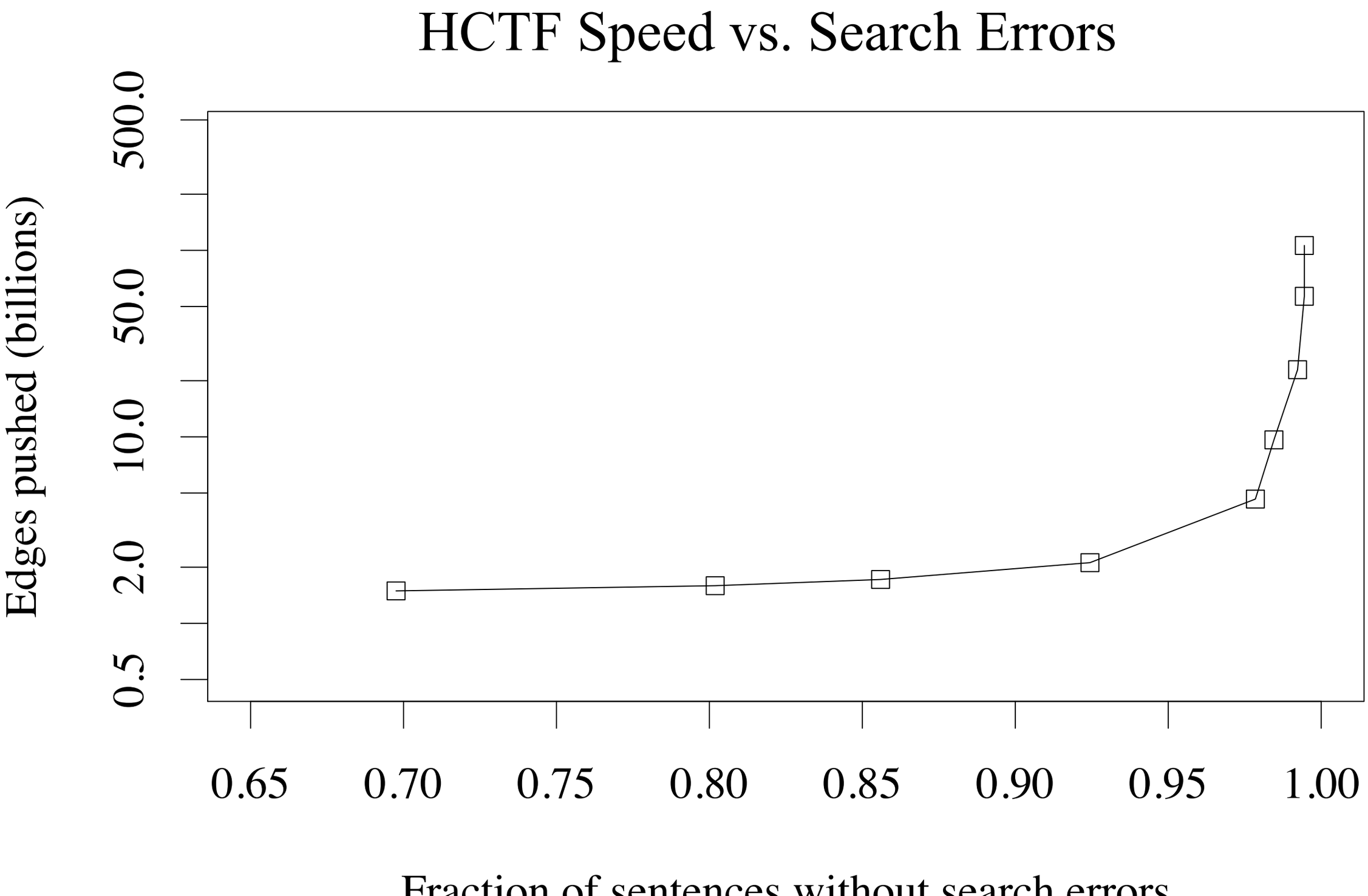
Why A*?

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

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

Cost of Optimality: State-Split Grammars



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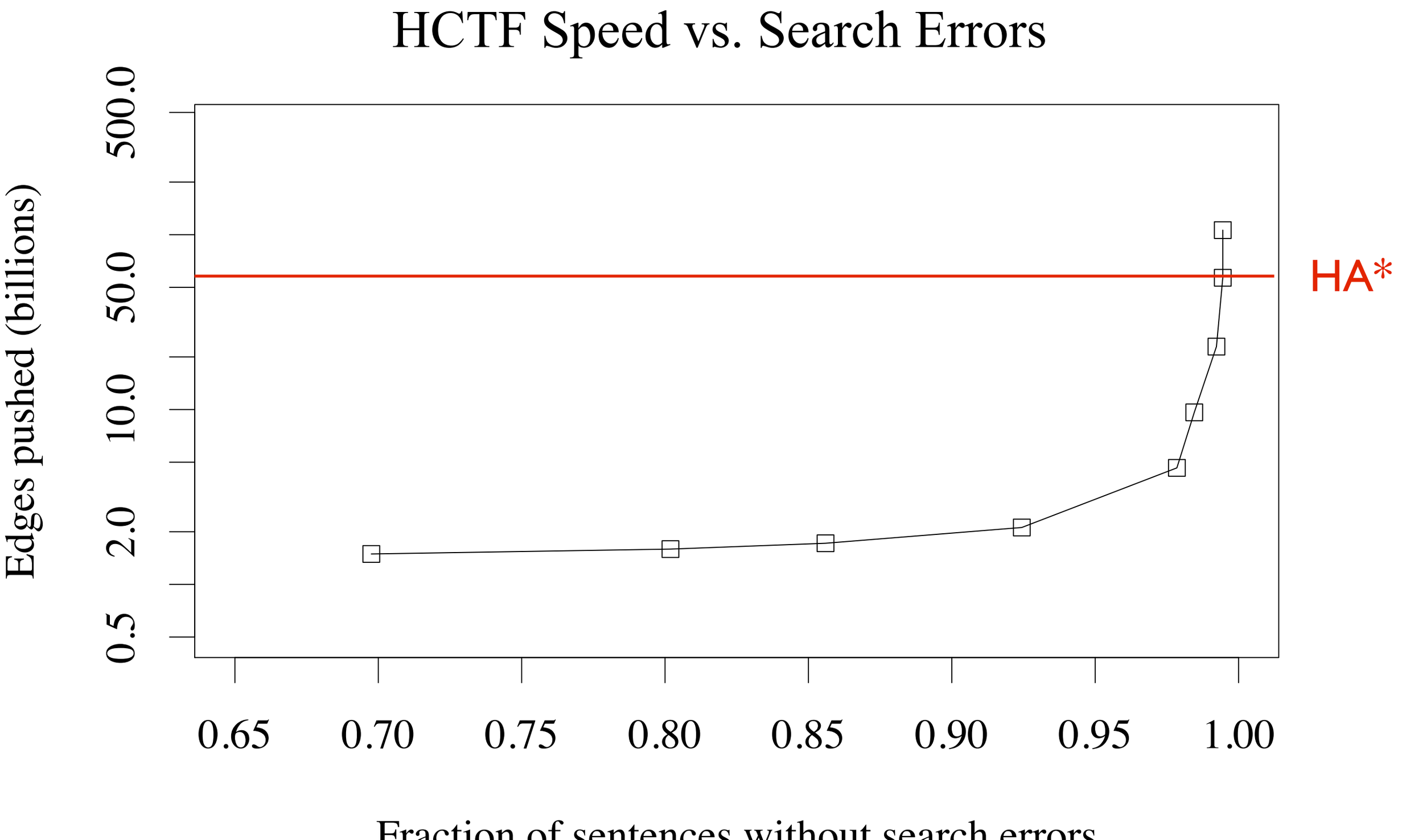

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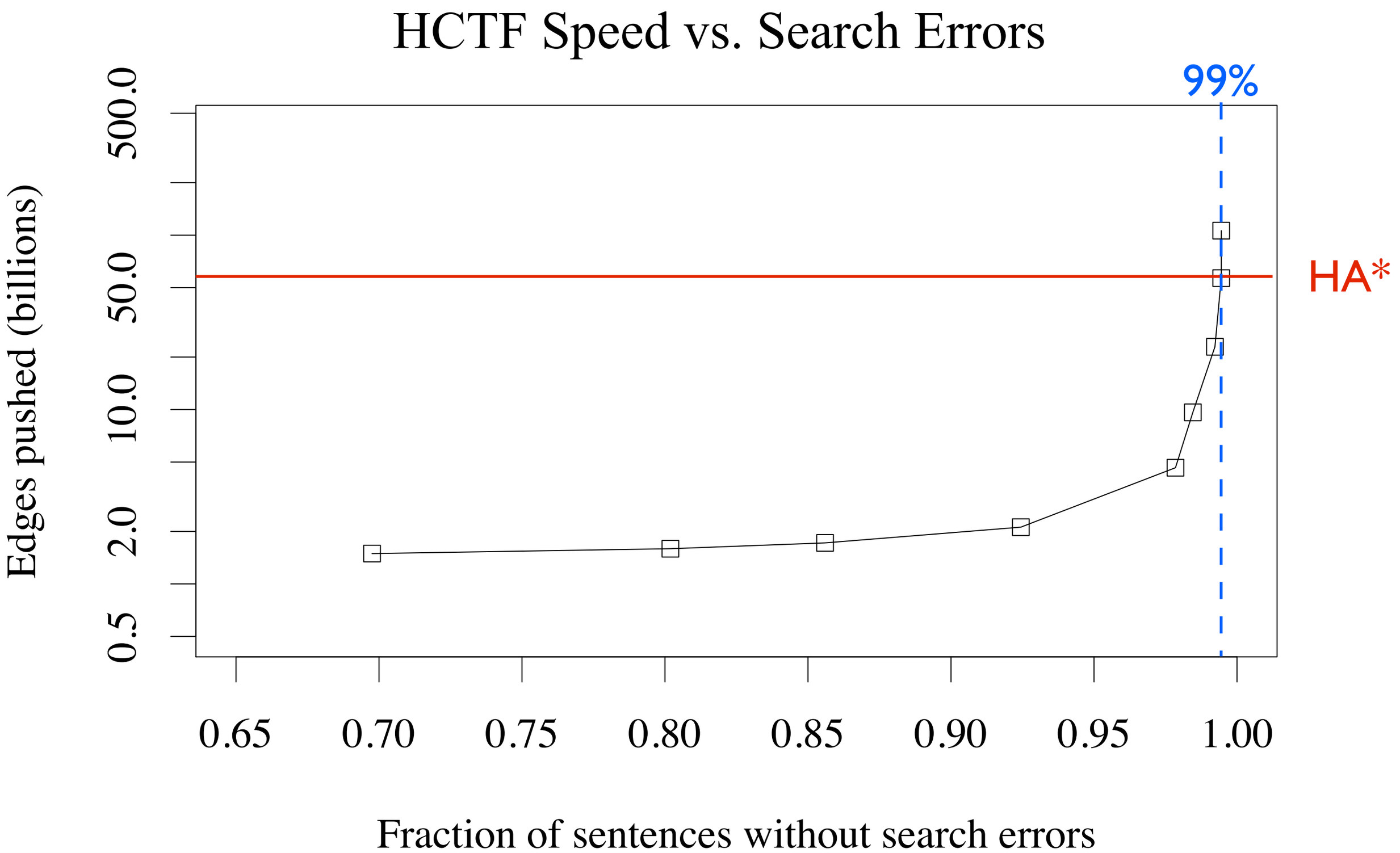

Why A*?

- 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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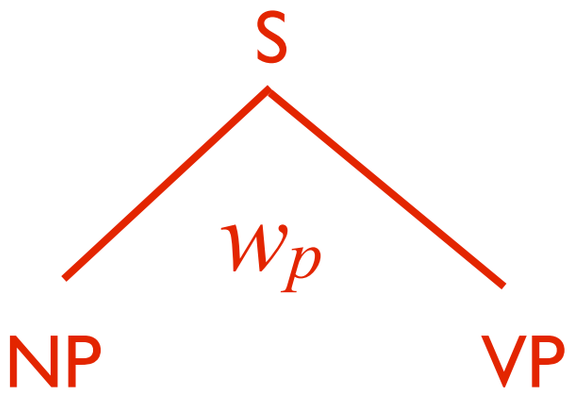

PCFG

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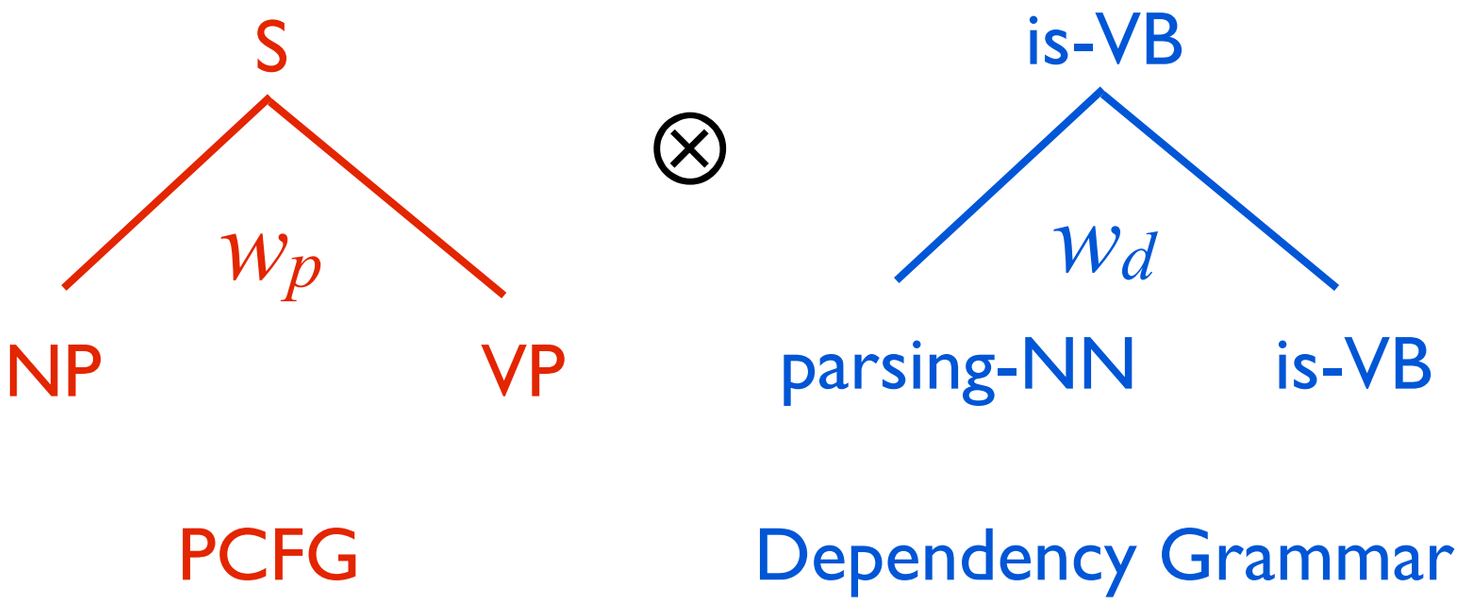

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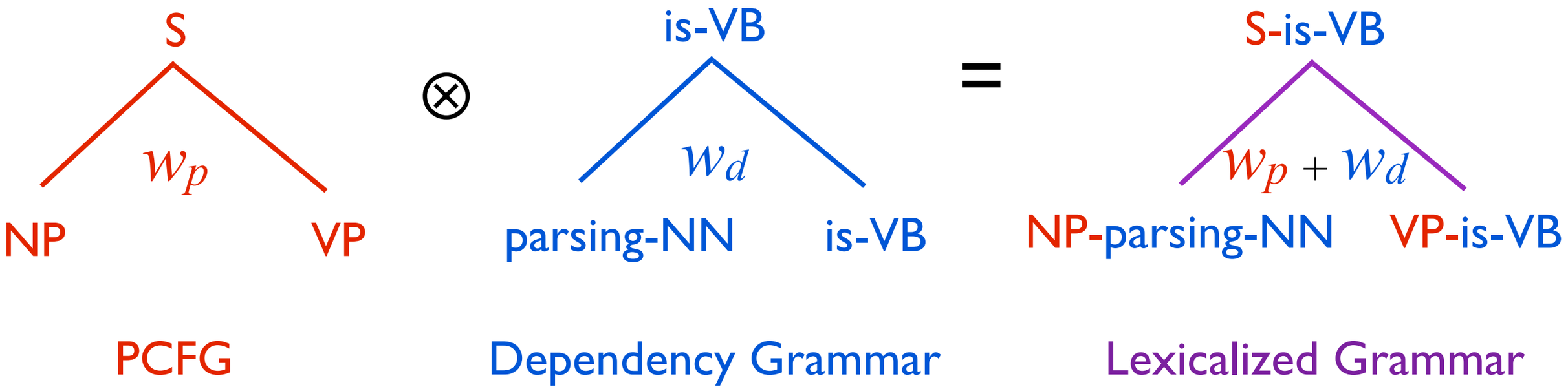
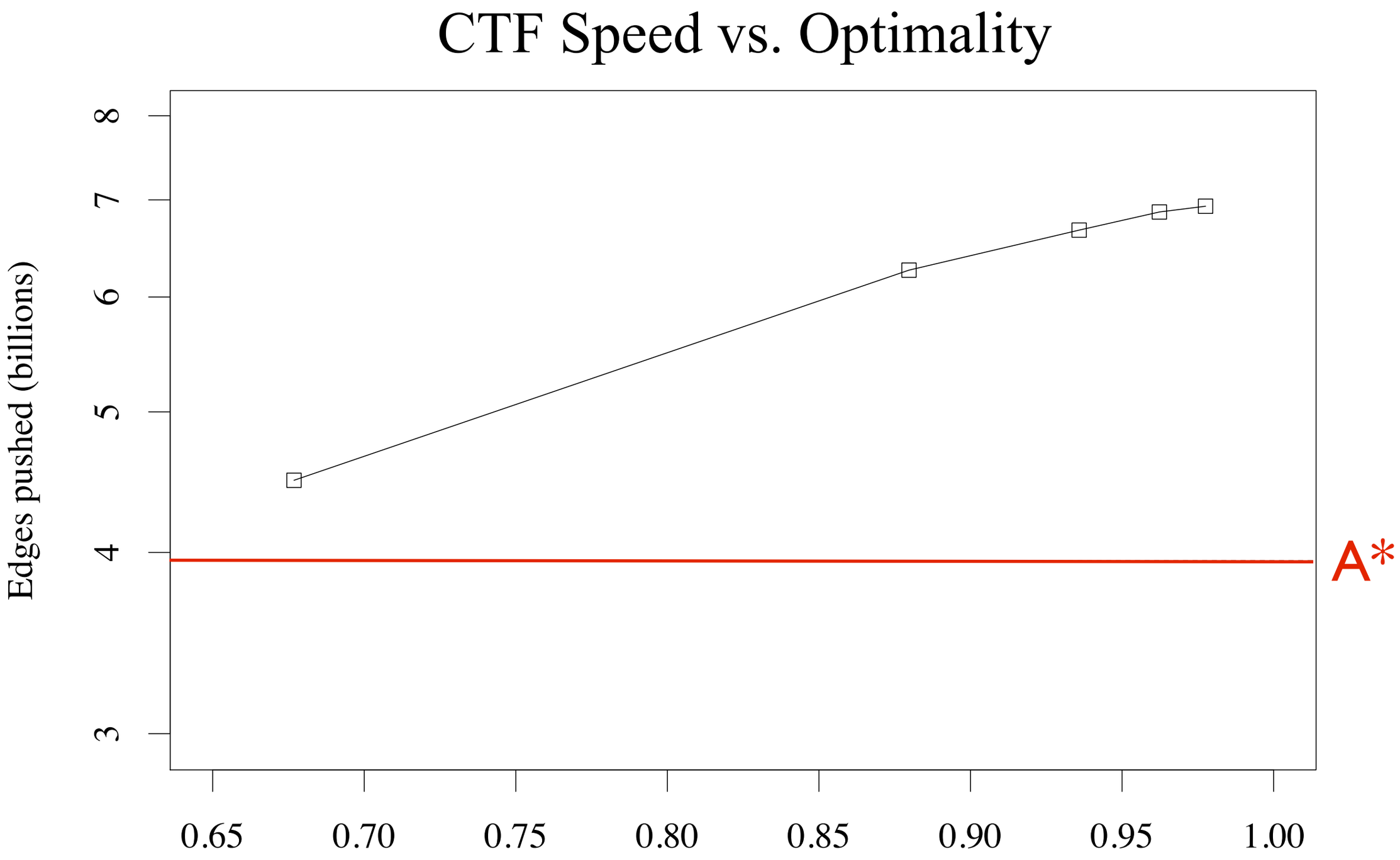


Cost of Optimality: Lexicalized Grammar



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