# Efficient Parsing for Transducer Grammars

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# Overview

- Syntactic decoding can decompose into two phases: parsing and language model integration

- The parsing phase alone is time consuming for large tree transducer grammars

- Grammar transformations, optimizations, and coarse-to-fine techniques increase parsing speed

- The accelerated parsing pass improves translation

# Tree Transducer Grammars

No se olvide de subir un canto rodado en Colorado

**Synchronous Grammar**

**Output**

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***NNP*** → Colorado **;** *Colorado*

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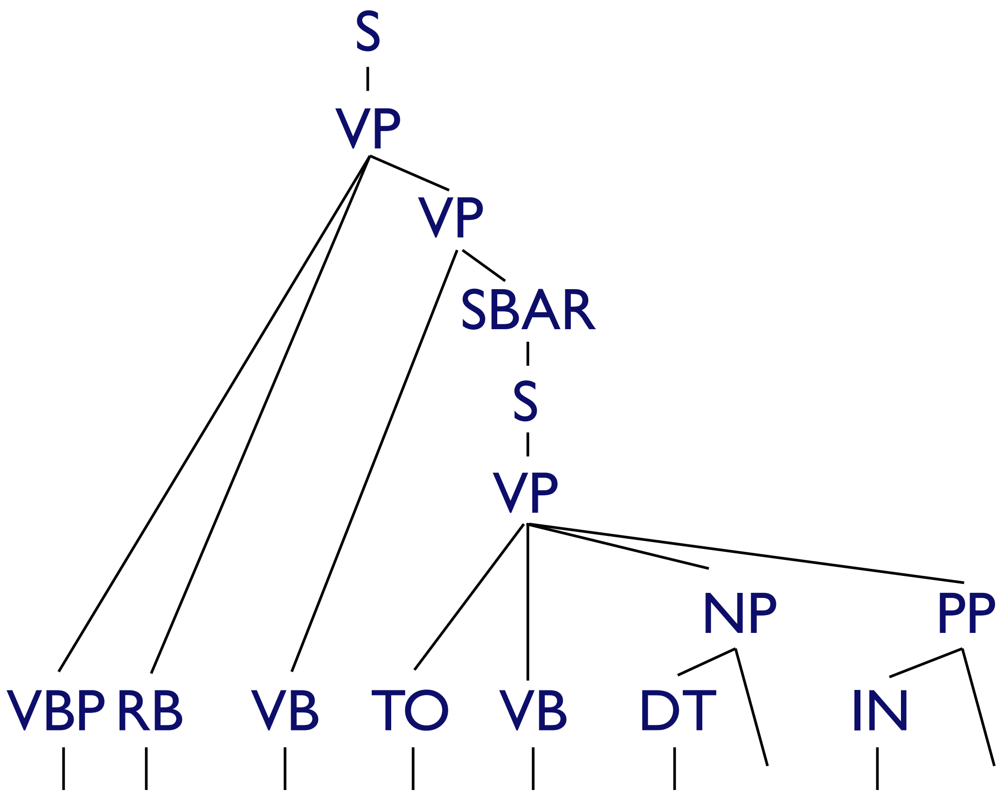

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NN

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**Output**

NN

boulder

# Tree Transducer Grammars

NN NNP

No se olvide de subir un canto rodado en Colorado

### Synchronous Grammar

***NNP*** → Colorado ; *Colorado*

***NN*** → canto rodado ; *boulder*

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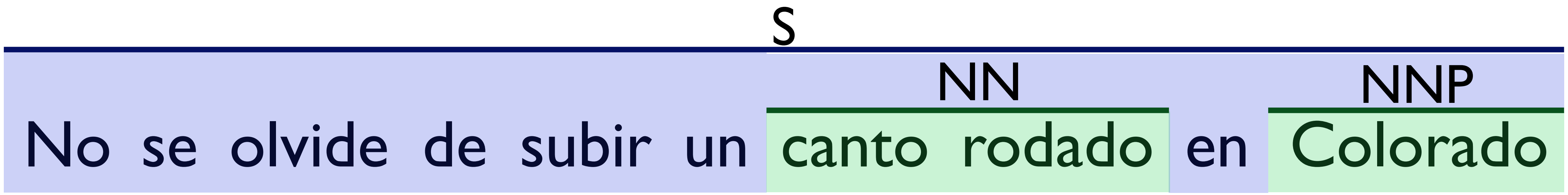
### Output

NN NNP

boulder Colorado

# Tree Transducer Grammars



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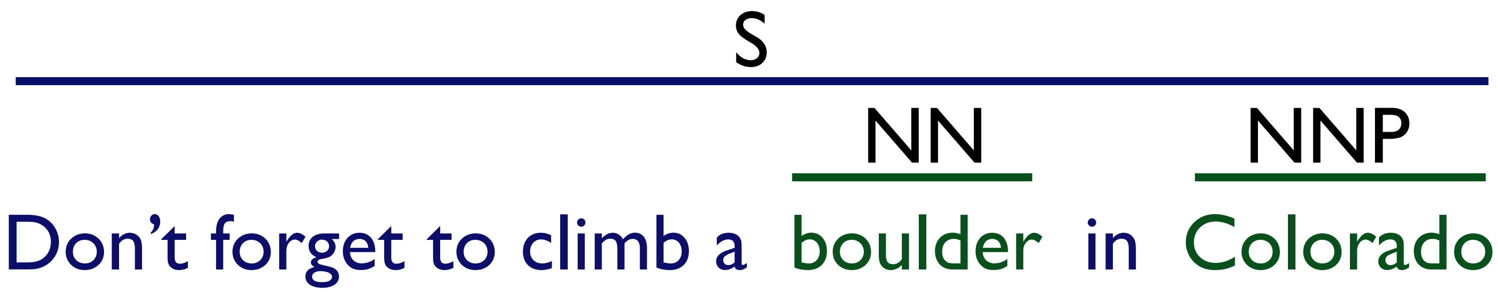
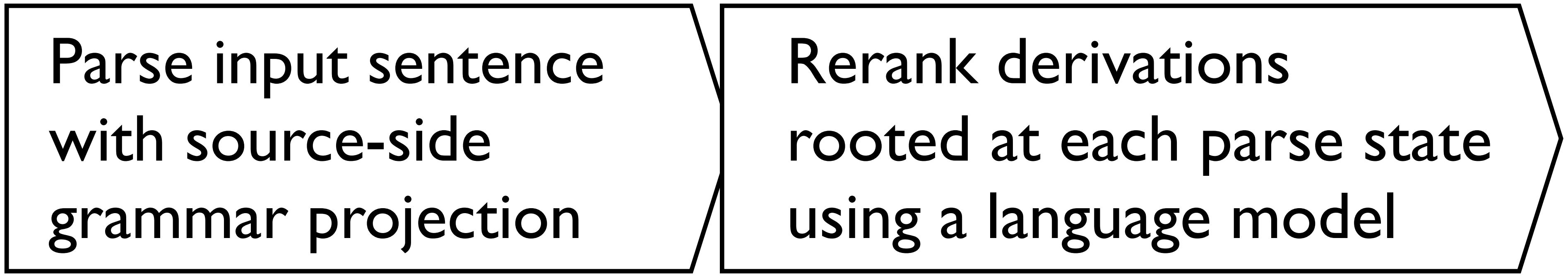


# Multi-Pass Syntactic Decoding



Parse input sentence with source-side grammar projection

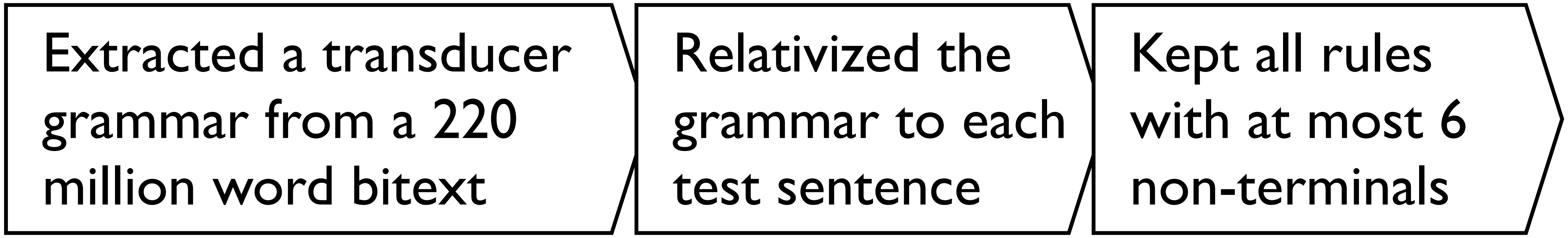
Rerank derivations rooted at each parse state using a language model

**Cube growing** [Huang and Chiang ’07]:
*Lazy forest reranking algorithm*

**Two-pass SCFG decoding** [Venugopal et al ’07]:
*Local search over derivations in a parse forest*

**Coarse-to-fine LMs** [Zhang et al ’08, Petrov et al ‘08]:
*Multi-pass bottom-up LM integration over forests*

# The Size of Tree Transducer Grammars



Extracted a transducer grammar from a 220 million word bitext

Relativized the grammar to each test sentence

Kept all rules with at most 6 non-terminals

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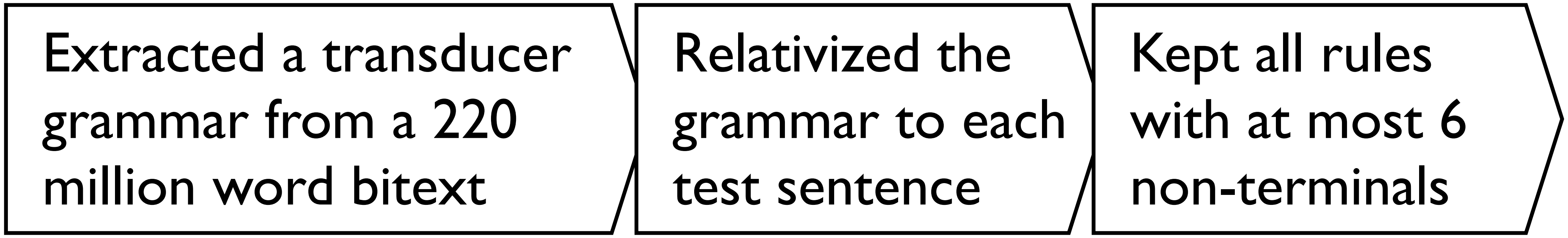

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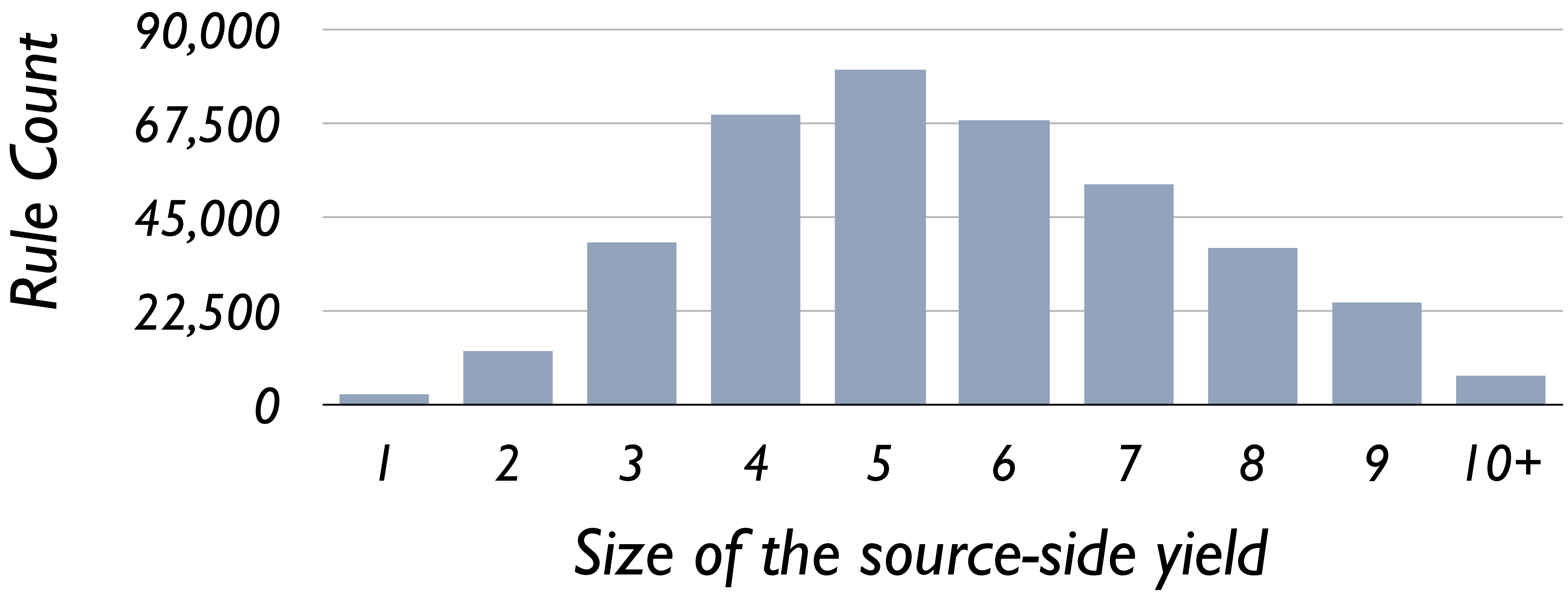
## Rules matching an example 40-word sentence



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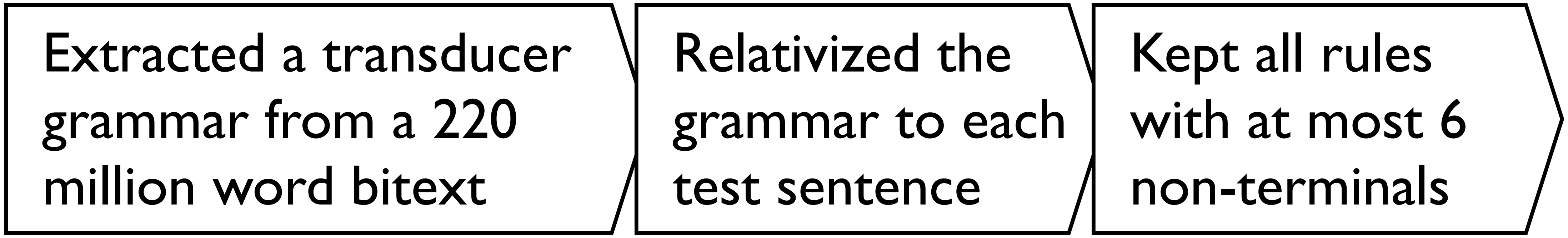

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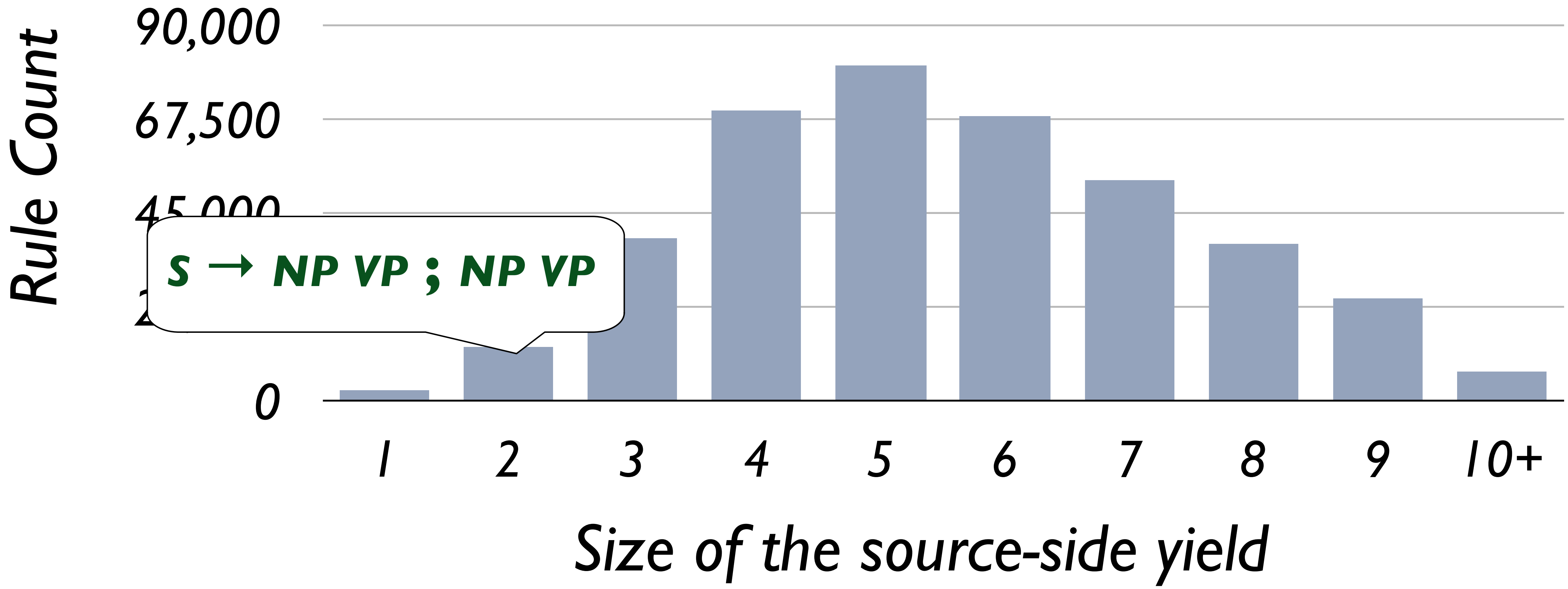

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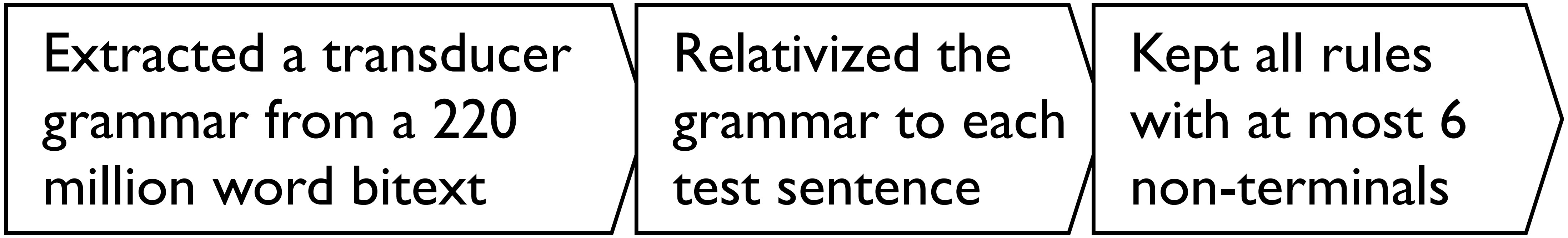

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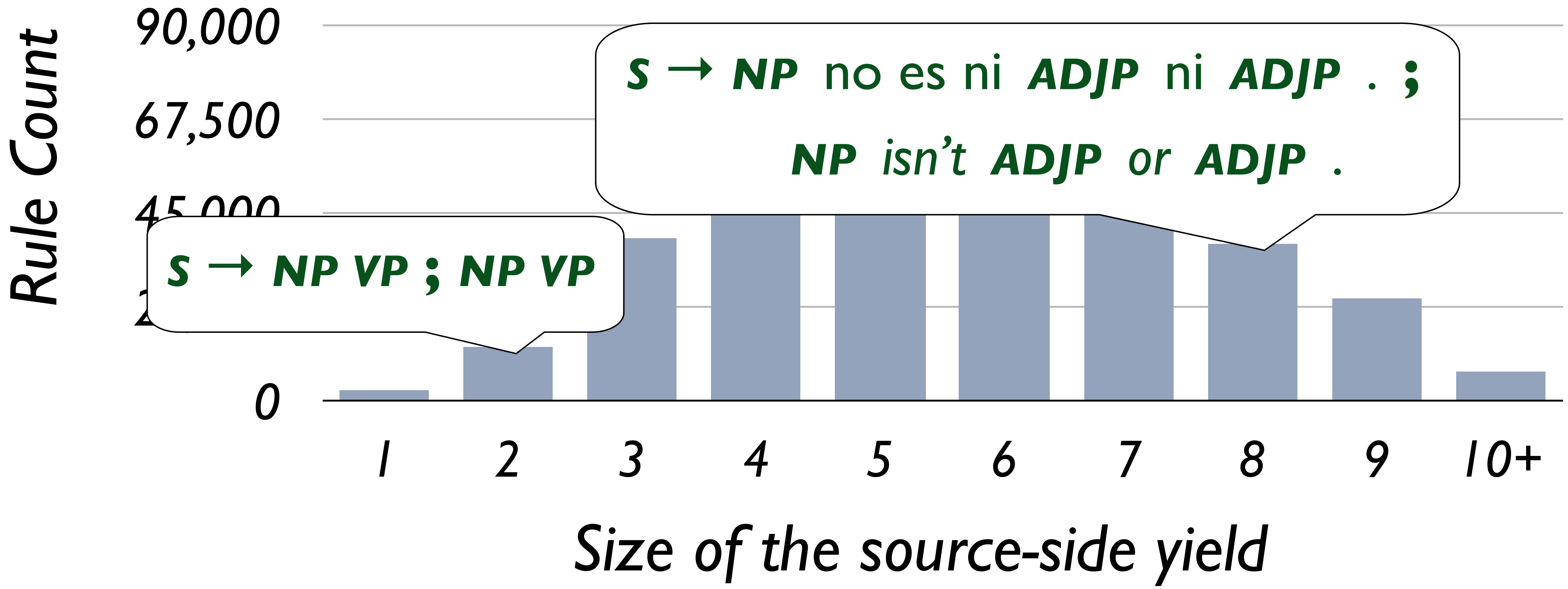

# CKY-style Bottom-up Parsing

For each
span length:

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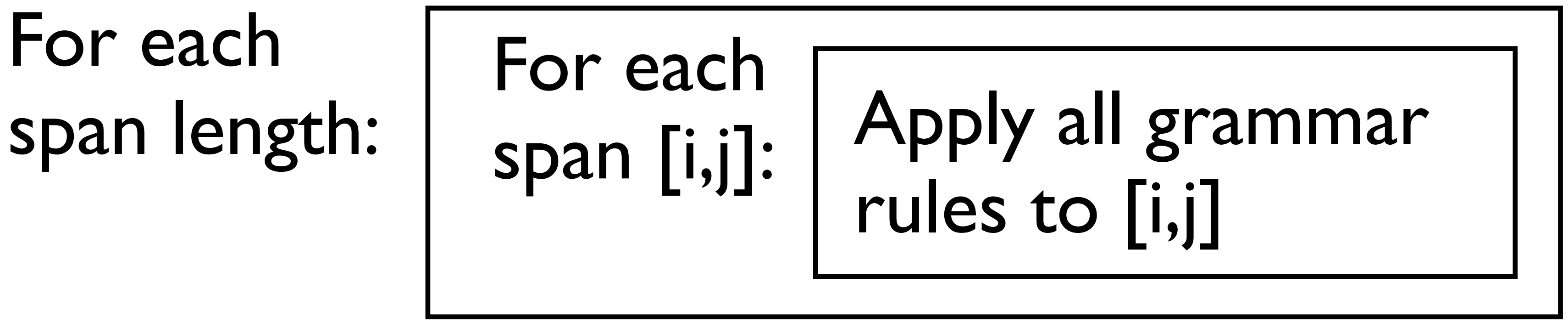

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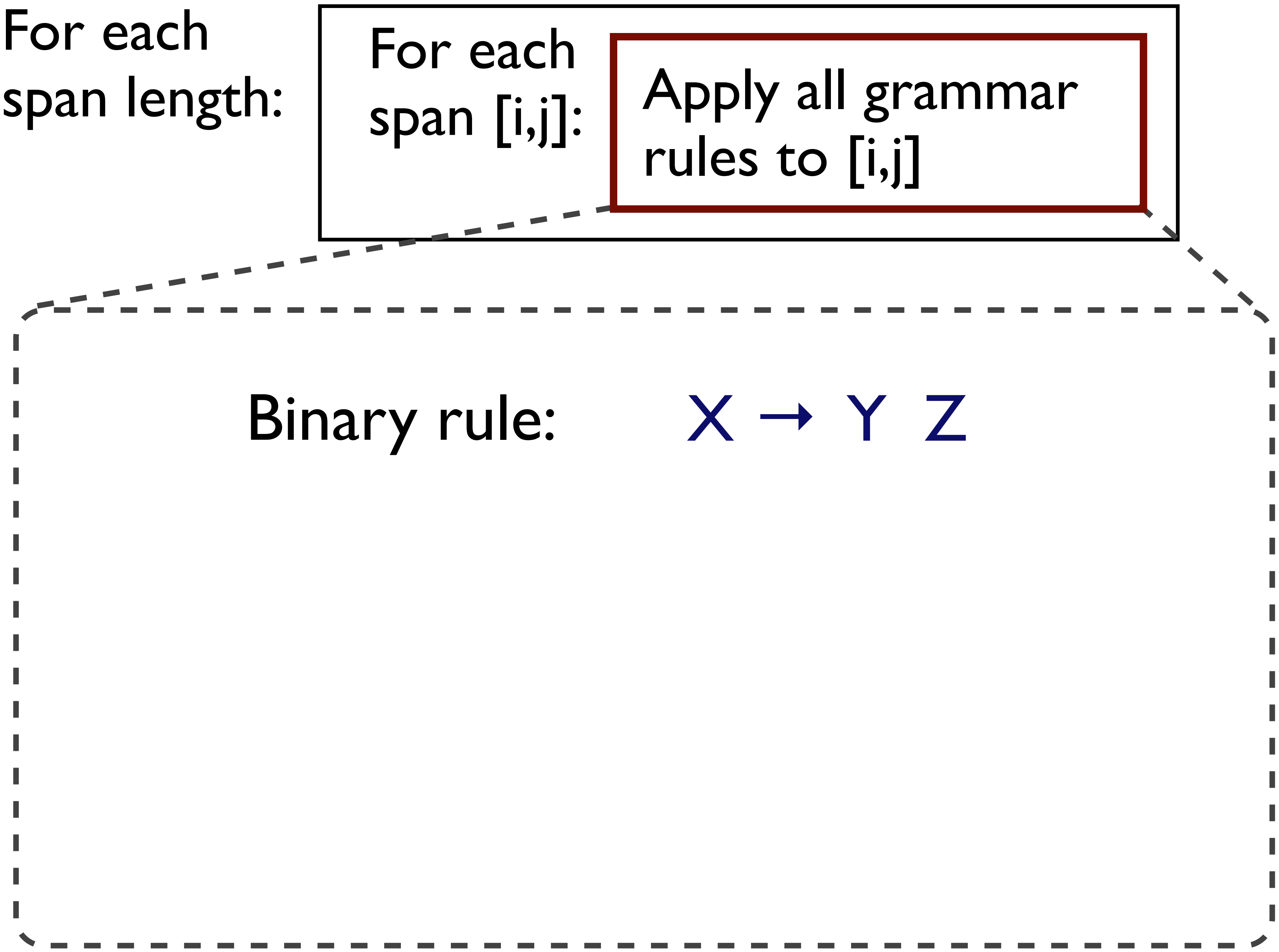

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Binary rule: $X \rightarrow Y \; Z$

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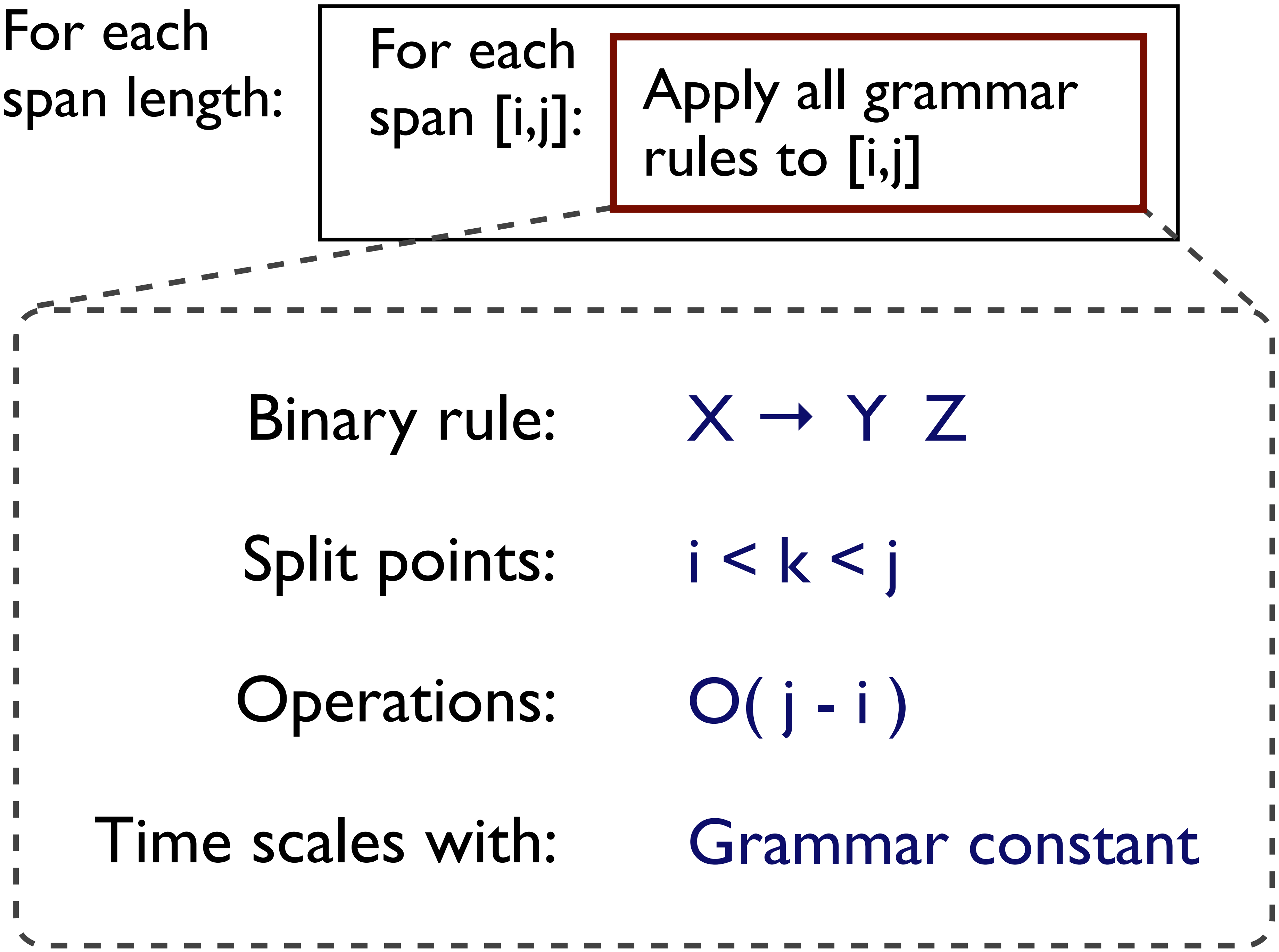

For each span length:

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Binary rule: X → Y Z

Split points: $i < k < j$

Operations: $O( j - i )$

Time scales with: Grammar constant

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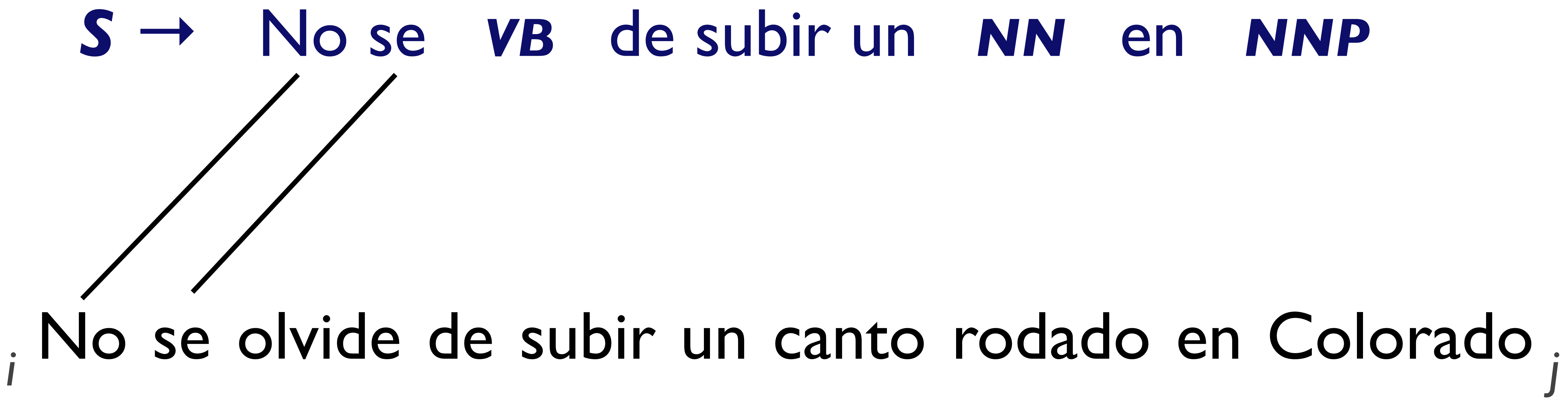

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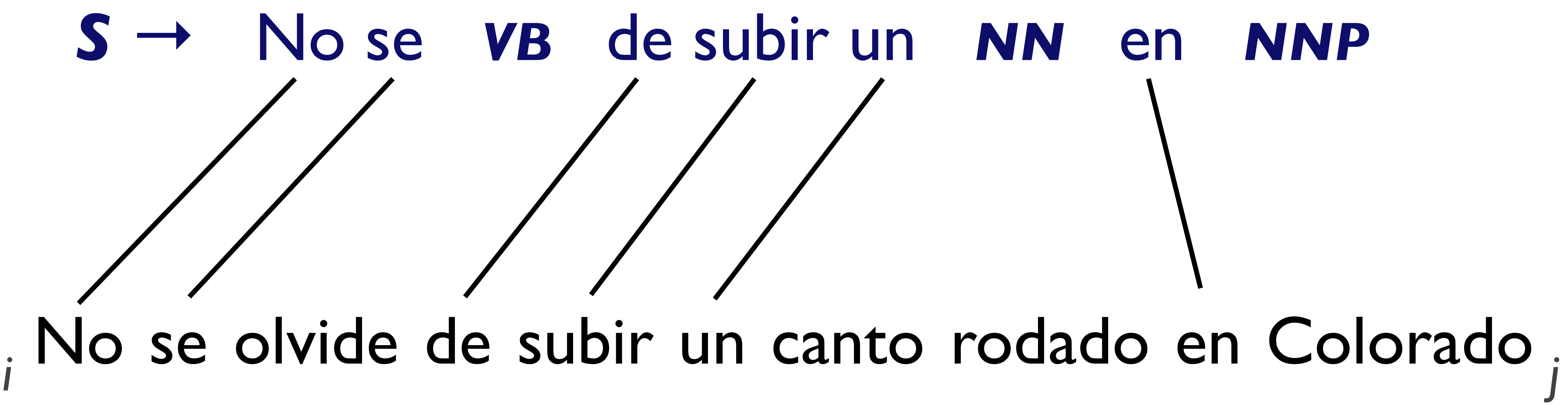

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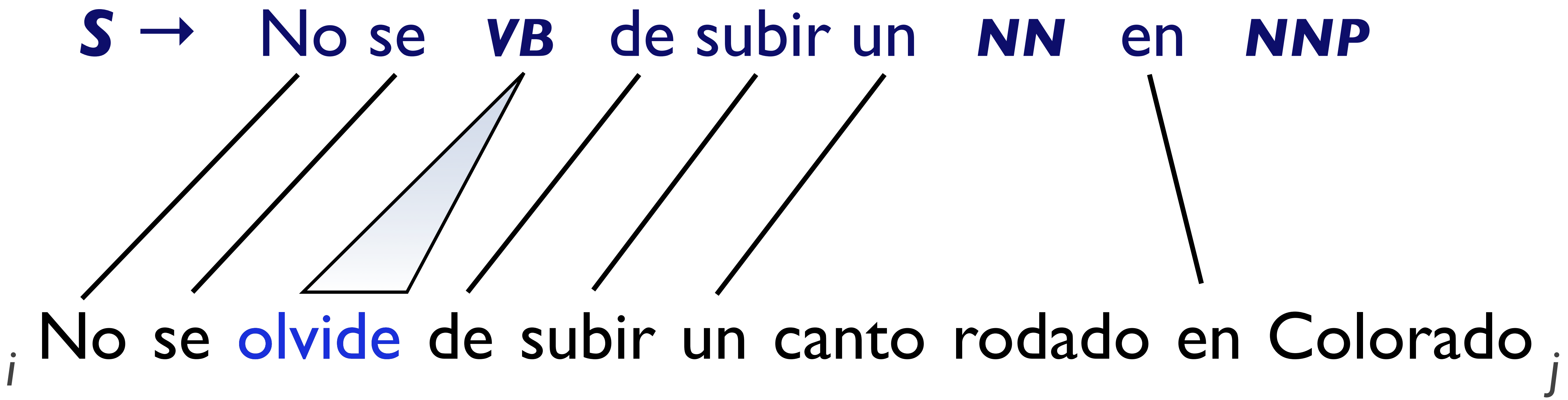

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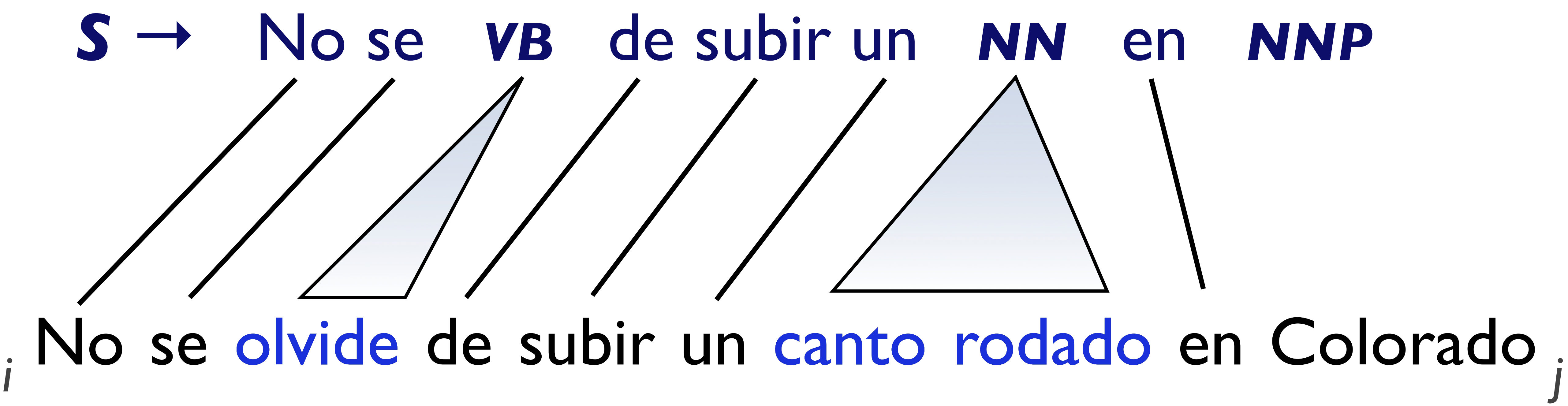

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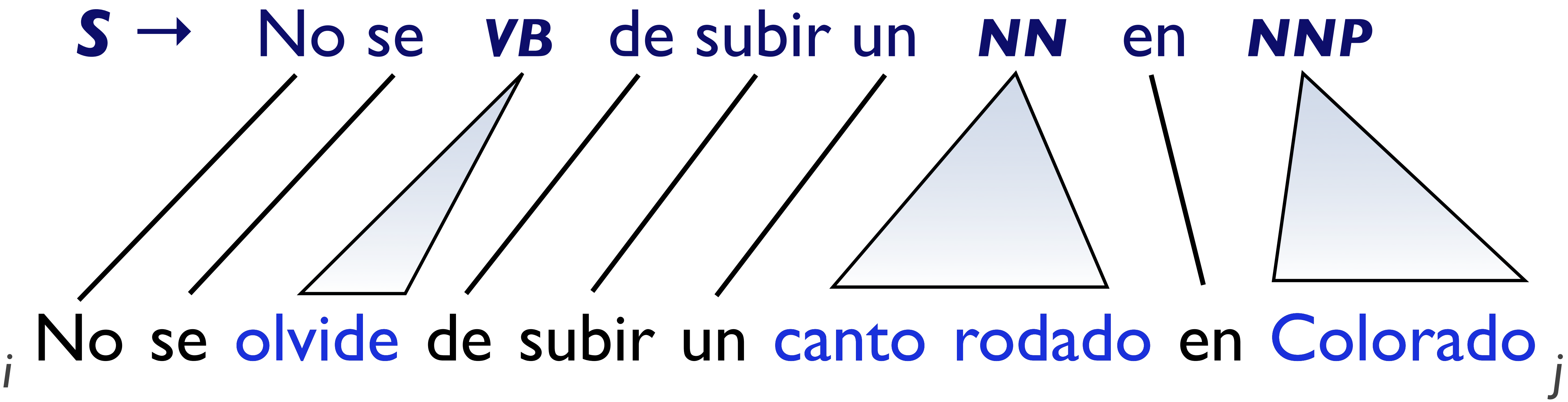
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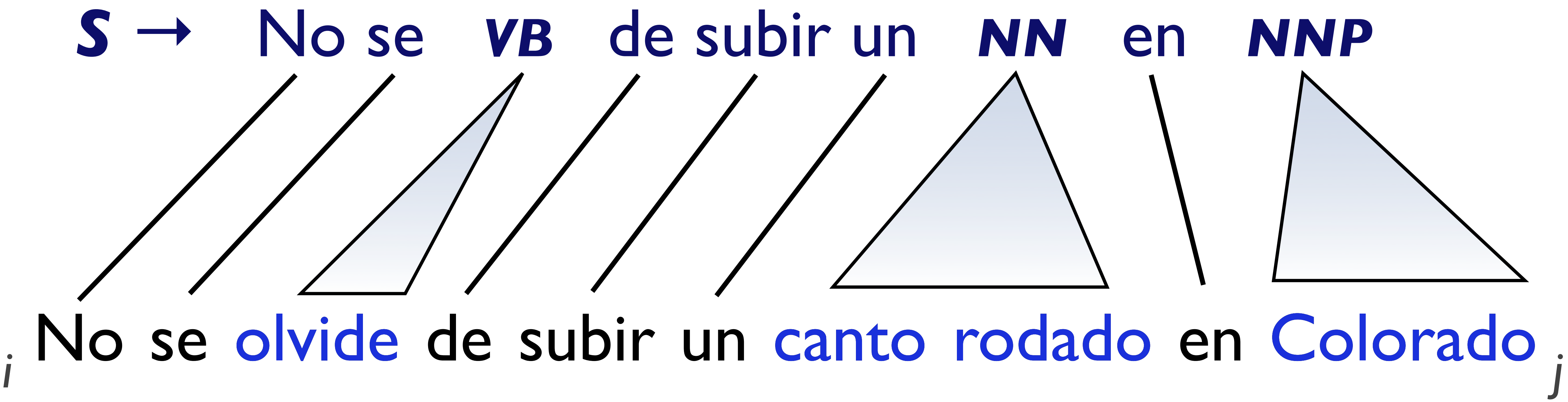

***S* → No se *VB* de subir un *NN* en *NNP***

*i* No se olvide de subir un canto rodado en Colorado *j*

*Many untransformed lexical rules can be applied in linear time*

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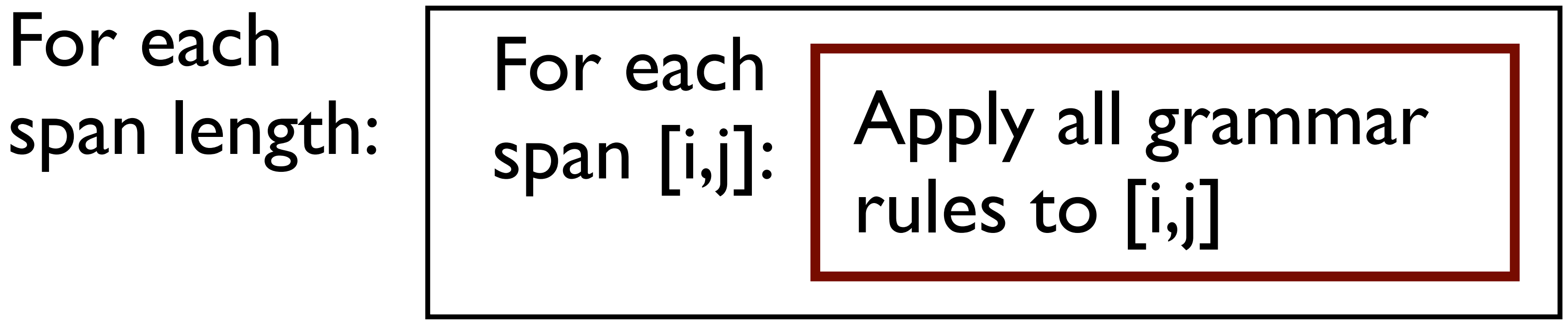

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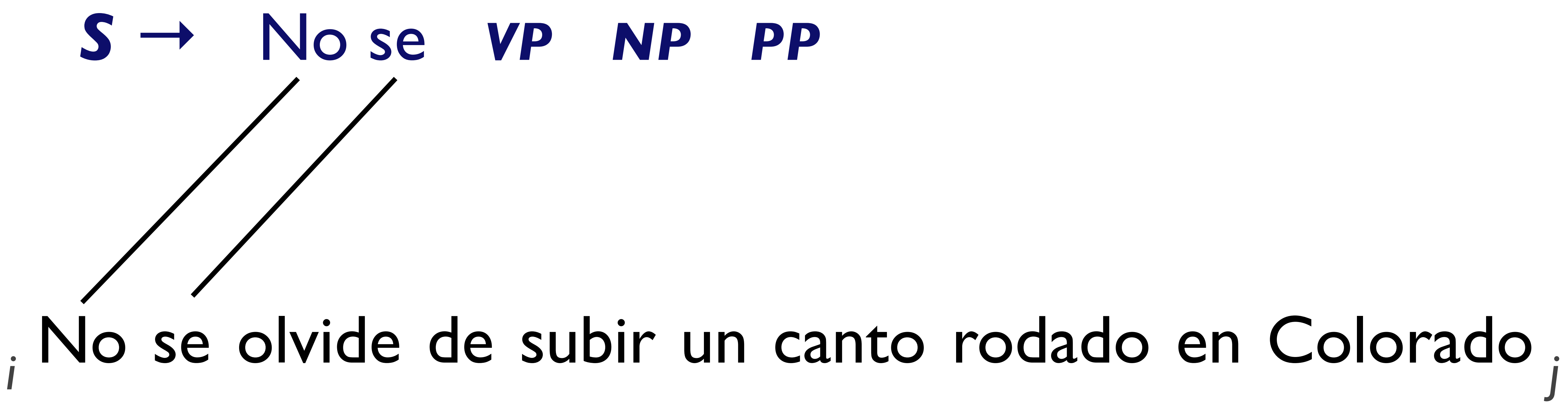

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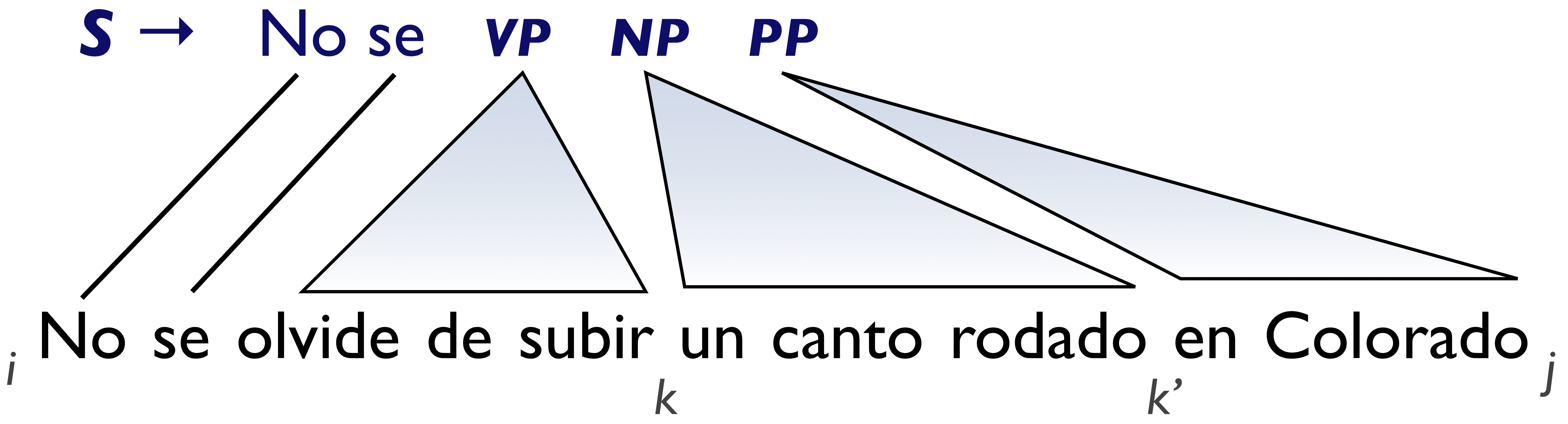

**S** → No se ***VP*** ***NP*** ***PP***

*i* No se olvide de subir *k* un canto rodado *k'* en Colorado *j*

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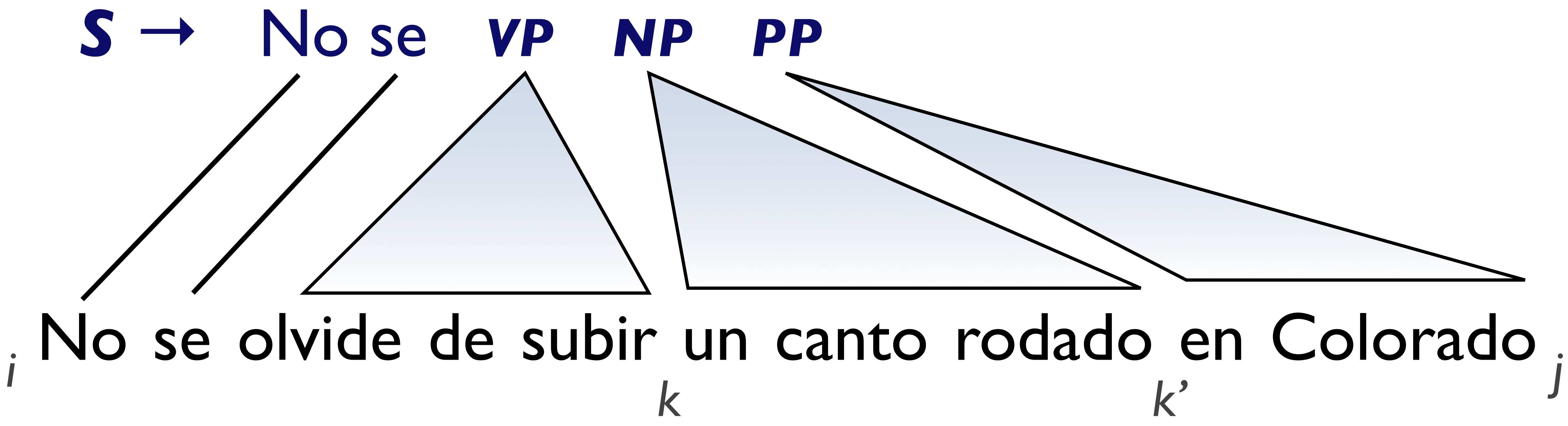

***S*** → No se ***VP*** ***NP*** ***PP***

No se olvide de subir un canto rodado en Colorado

***Problem:*** *Applying adjacent non-terminals is slow*

# Eliminating Non-terminal Sequences

**Lexical Normal Form (LNF)**

*(a) lexical rules have at most one adjacent non-terminal*
*(b) all unlexicalized rules are binary.*

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Original rule: ***S*** → No se ***VB*** ***VB*** un ***NN*** ***PP***

Transformed rules: ***S*** → No se ***VB~VB*** un ***NN~PP***

***VB~VB*** → ***VB*** ***VB***

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Parsing stages:

- Lexical rules are applied by matching
- Unlexicalized rules are applied by iterating over split points

# Eliminating Non-terminal Sequences

## Lexical Normal Form (LNF)

*(a) lexical rules have at most one adjacent non-*

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SPEED
LIMIT
**68**
sentences
per hour

Original rule: ***S*** → No se ***VB*** ***VB*** un

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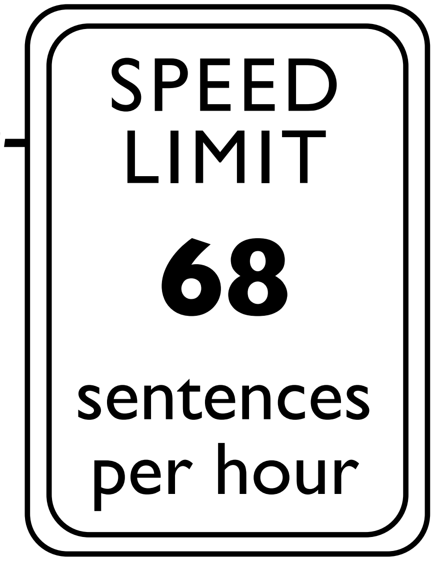

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# Bounding Split Points

***Problem:*** *Applying binary rules performs wasted work*

***VP~VP*** → ***VP*** ***VP***

$_i$No se olvide de subir un canto rodado en Colorado$_j$

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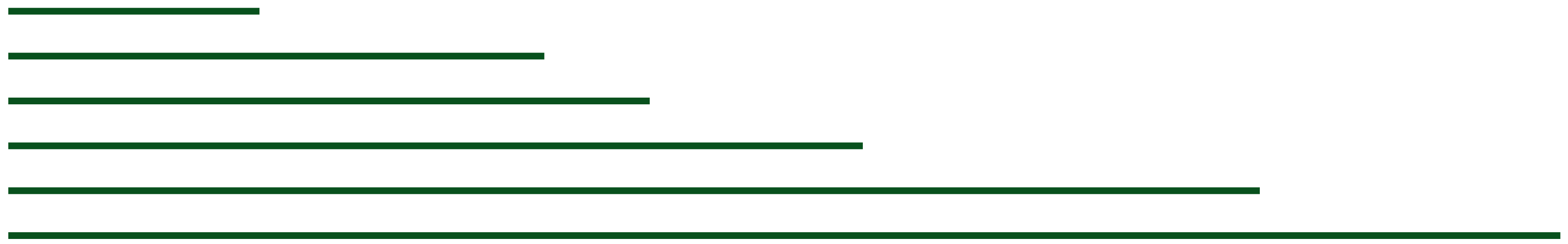
***VP∼VP → VP VP***



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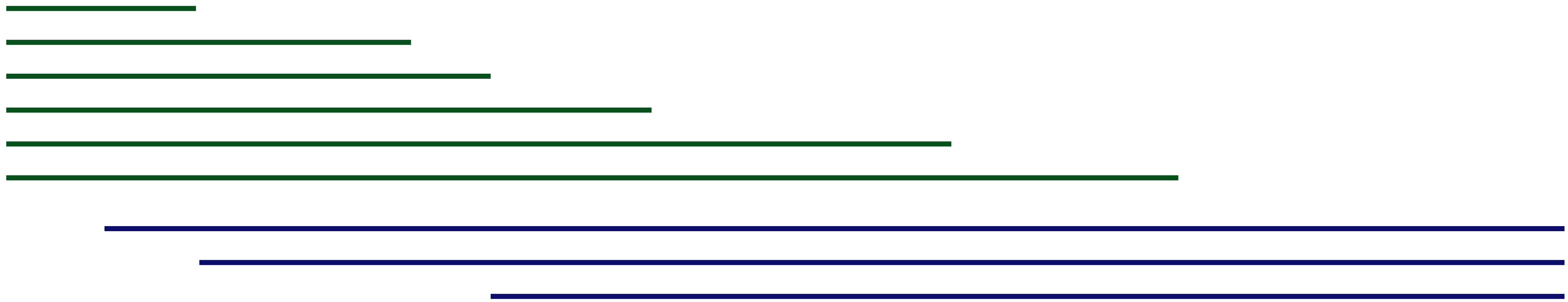

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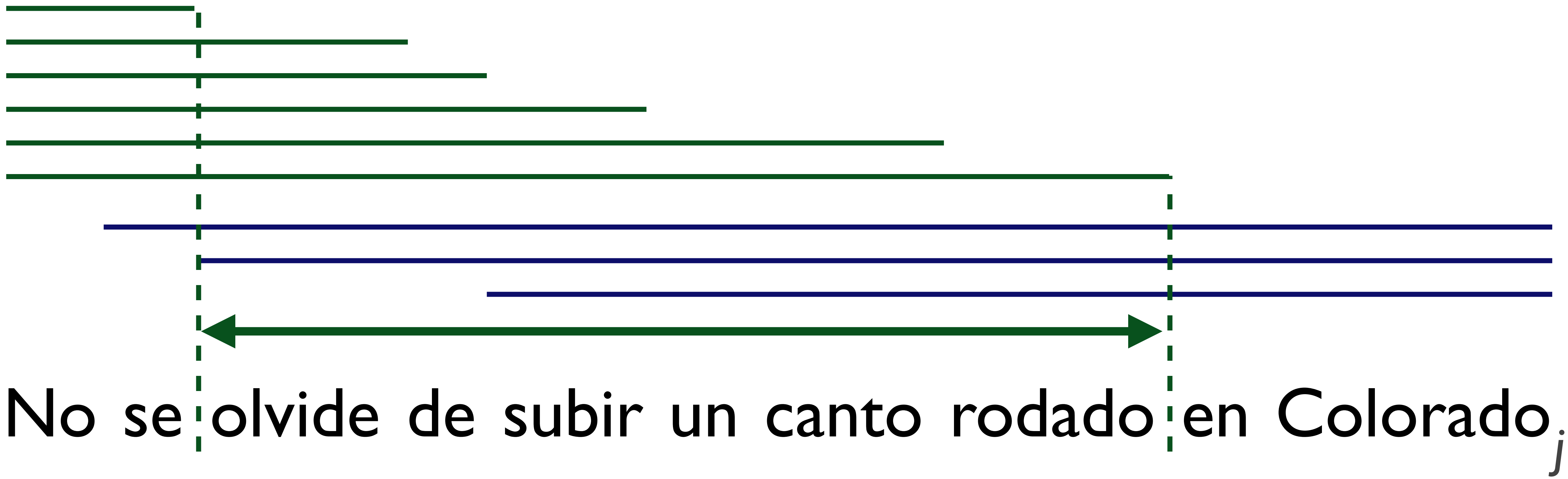

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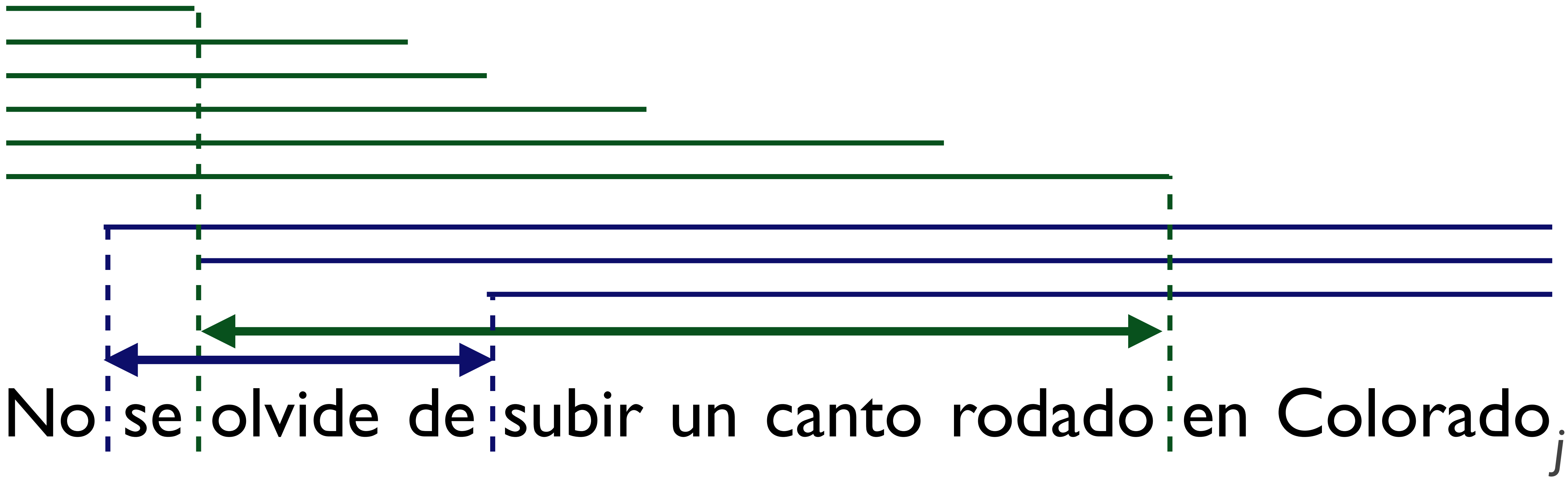

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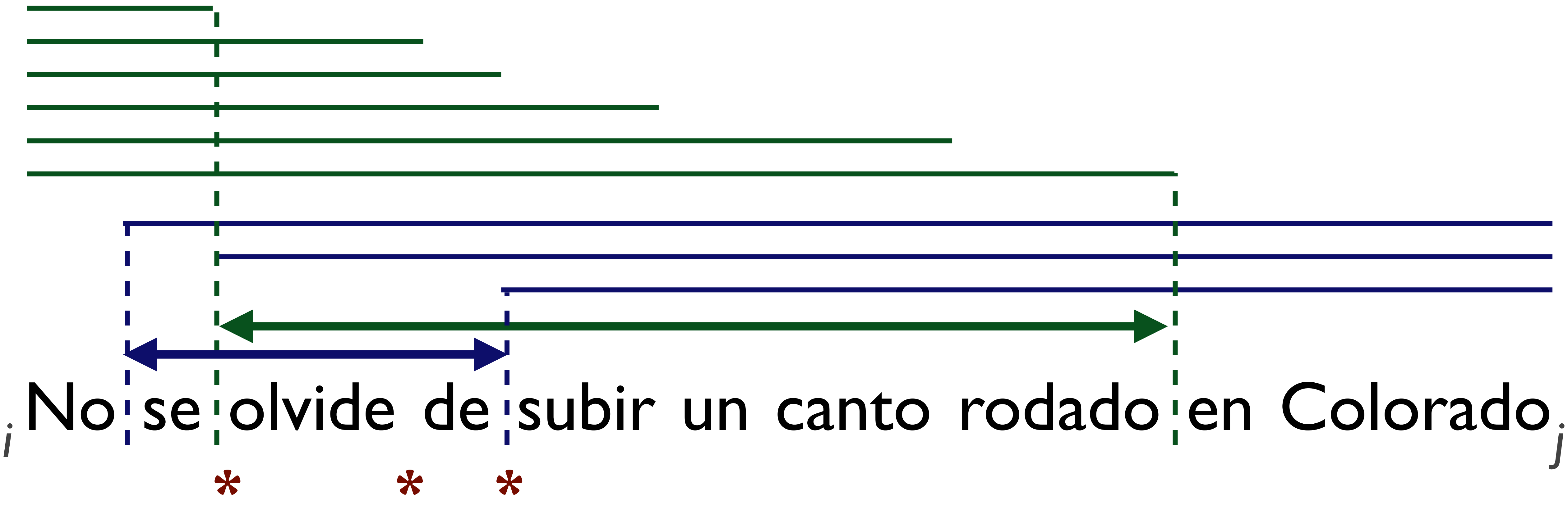

*Only consider split points k that might result in a valid parse*

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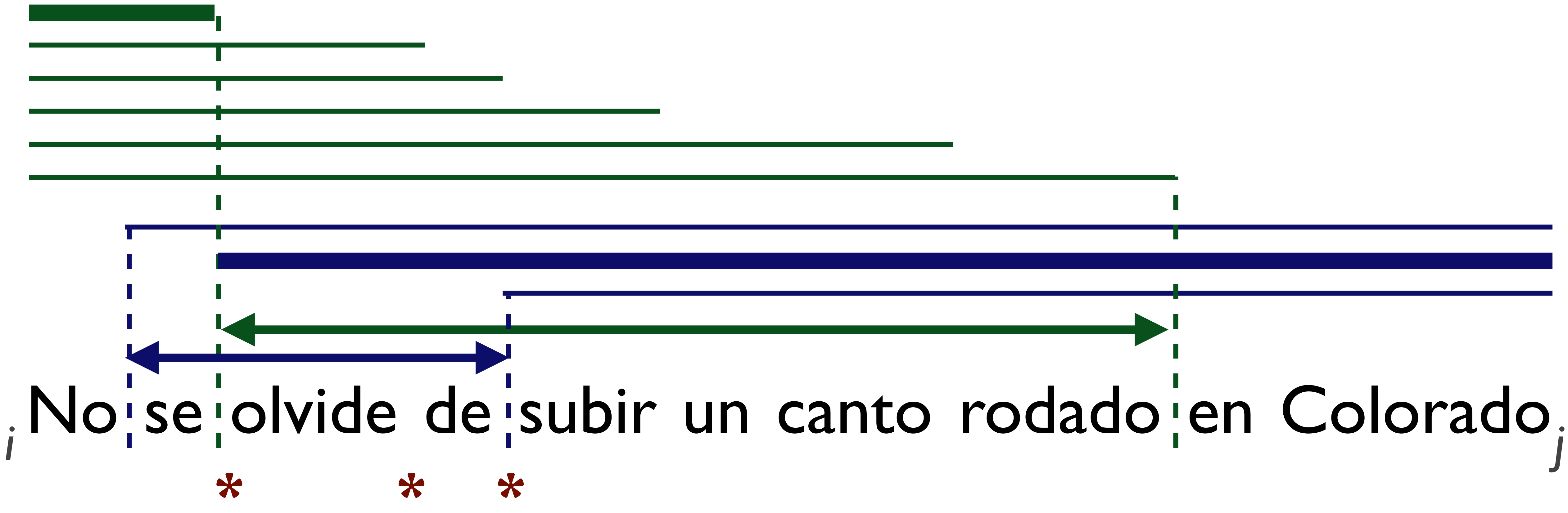

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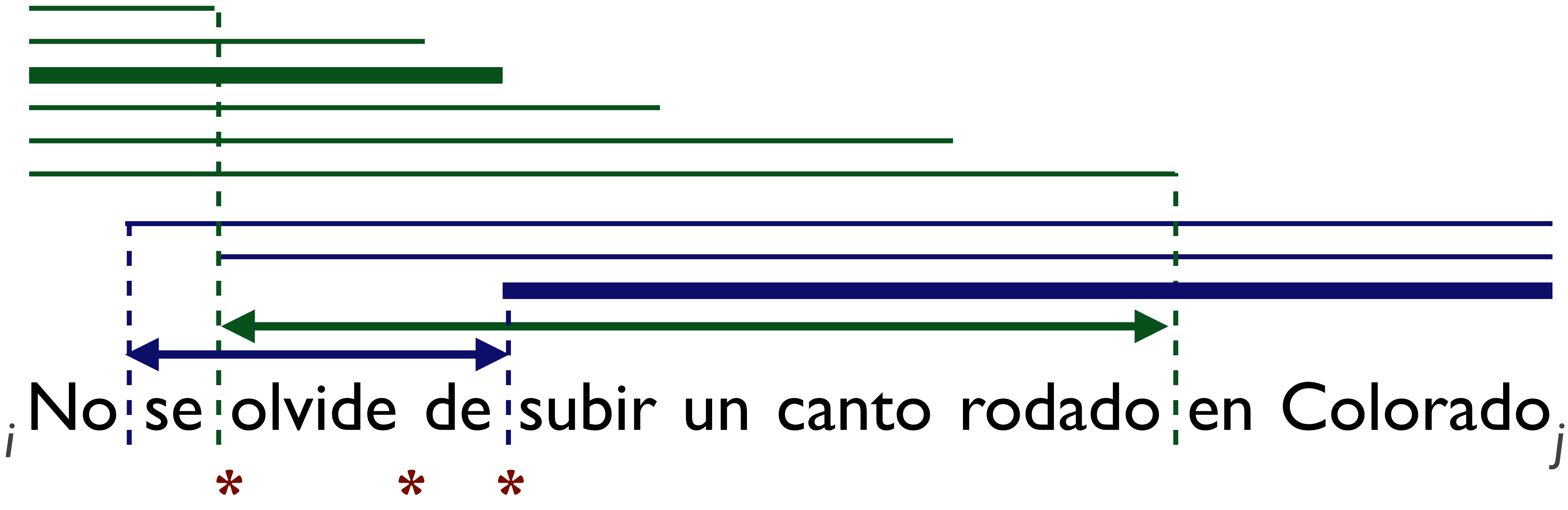

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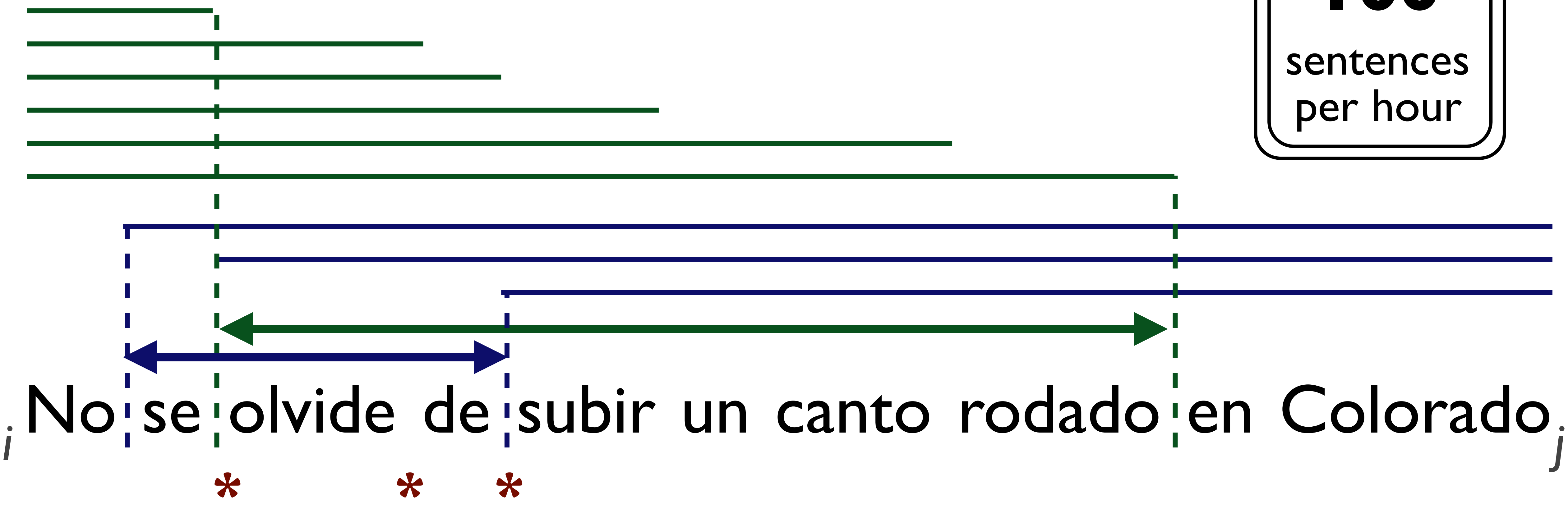
# Bounding Split Points

**Problem:** *Applying binary rules performs wasted work*

***VP~VP → VP VP***

SPEED
LIMIT
**100**
sentences
per hour



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# Speeding up Lexical Rule Application

***Problem:*** *Lexical rules can apply to many spans*

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***Problem:*** *Lexical rules can apply to many spans*

***S*** → No se olvide de subir ***NP***

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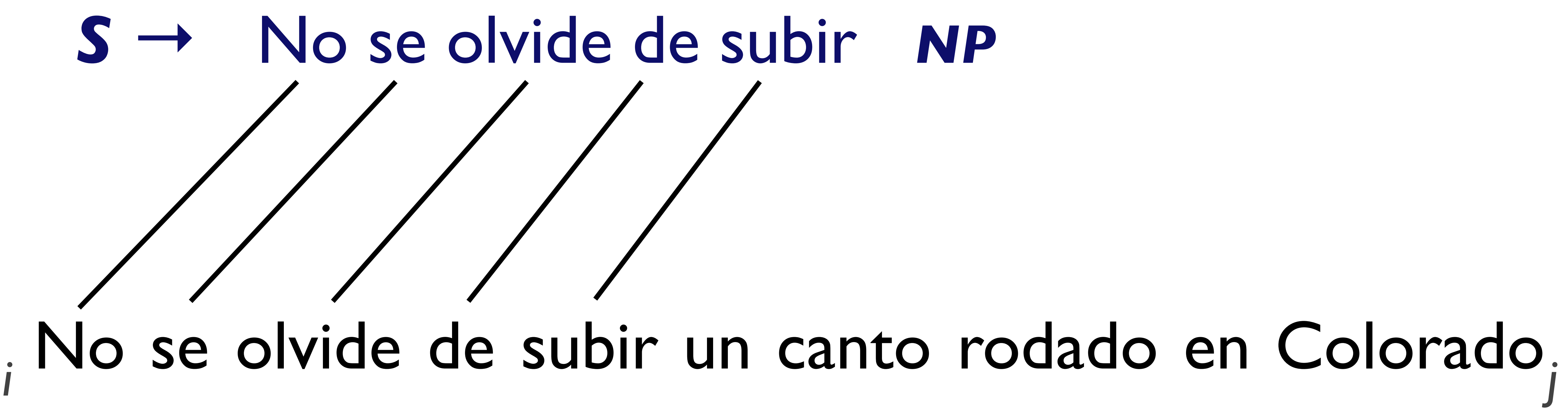

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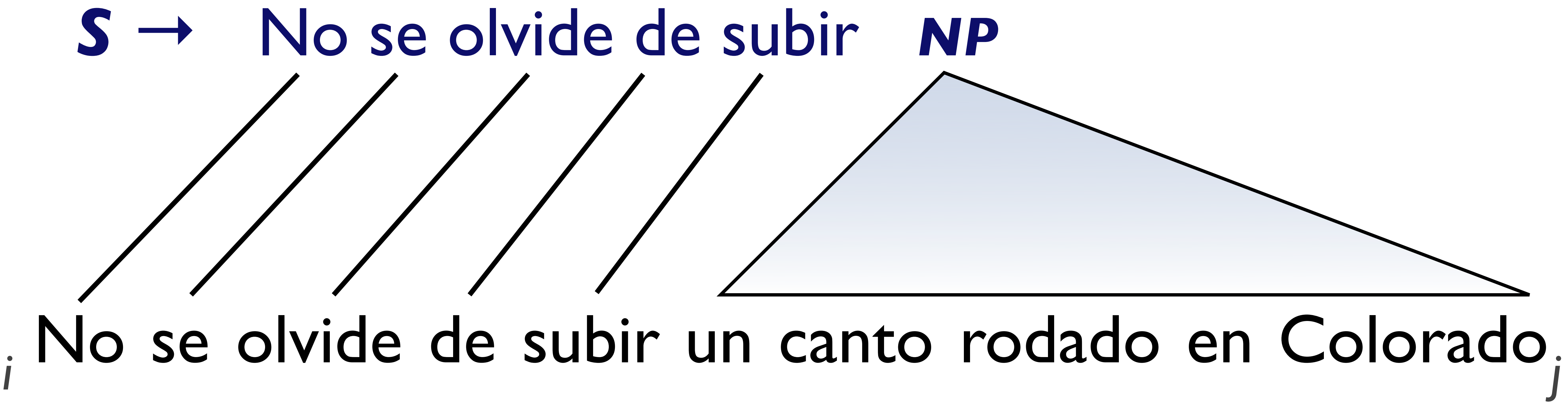
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i
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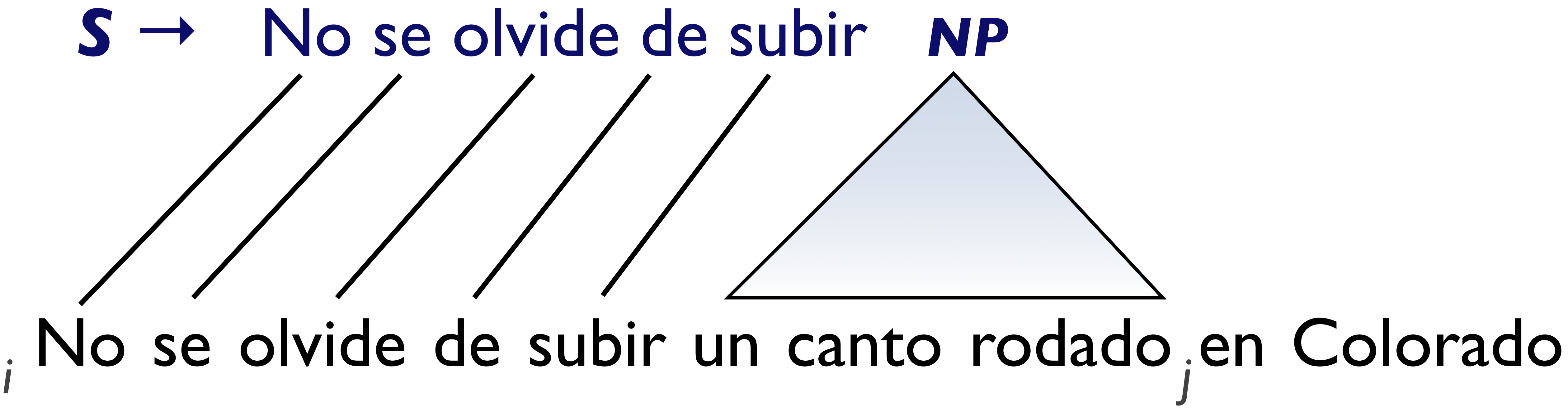

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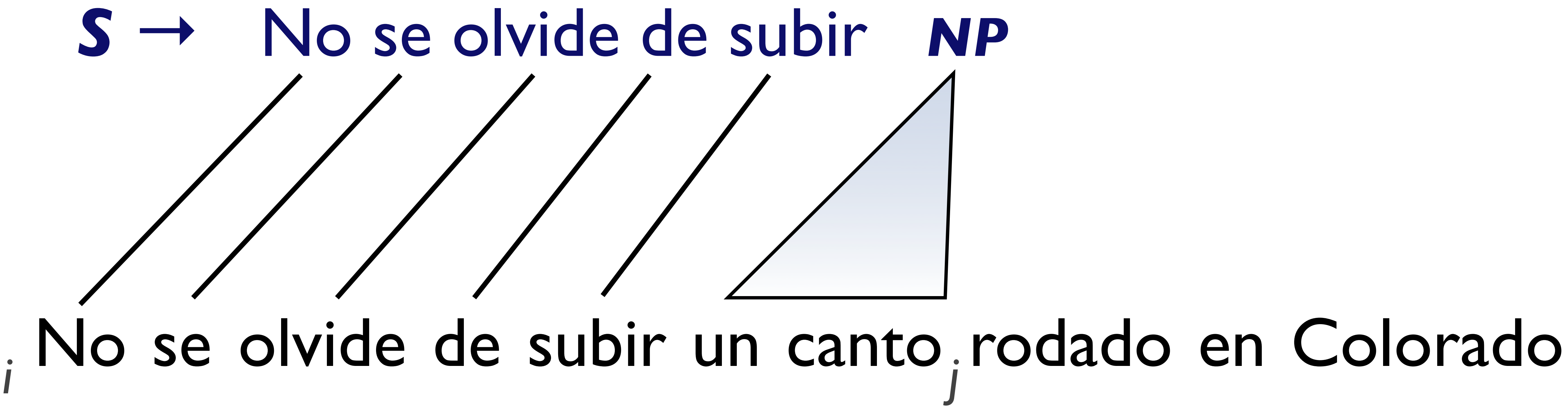

***S*** → No se olvide de subir ***NP***

$_i$ No se olvide de subir un canto $_j$ rodado en Colorado

# Speeding up Lexical Rule Application

**Anchored Lexical Normal Form (ALNF)**

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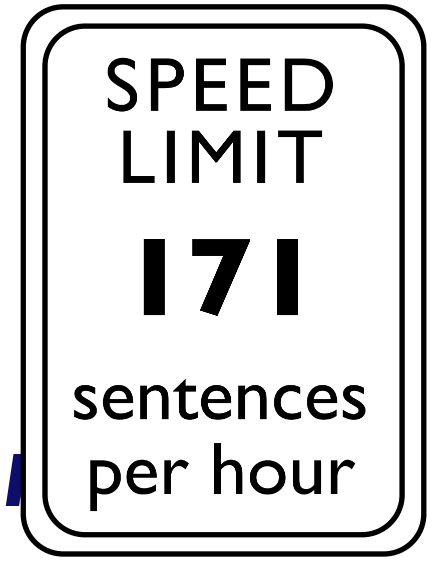

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# Binarizing Sequences of Non-Terminals

*We must select a binary derivation for each non-terminal sequence*

**Original:**

***S*** → ***VB NP NP PP***

**Binarization options:**

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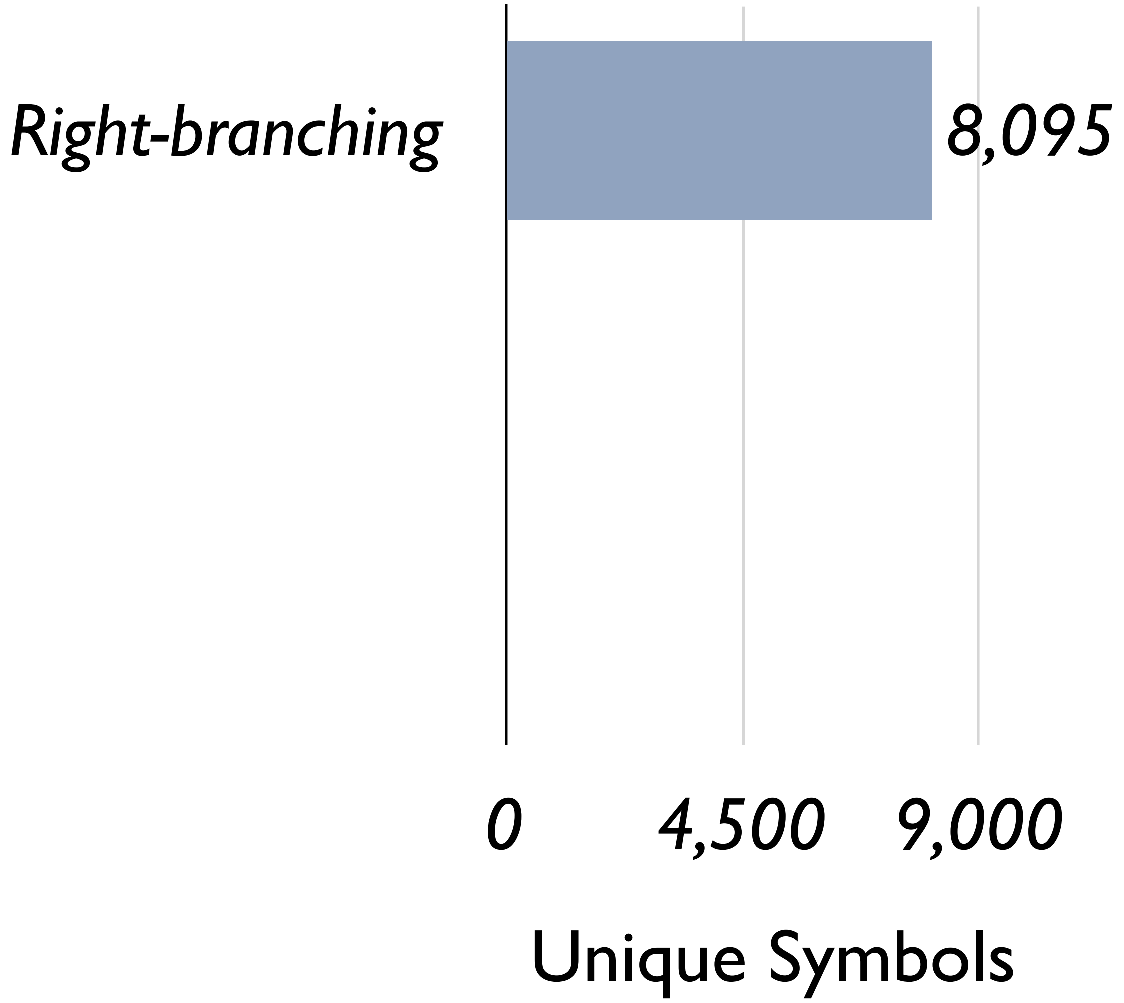
Binarization of an example sentence-specific grammar



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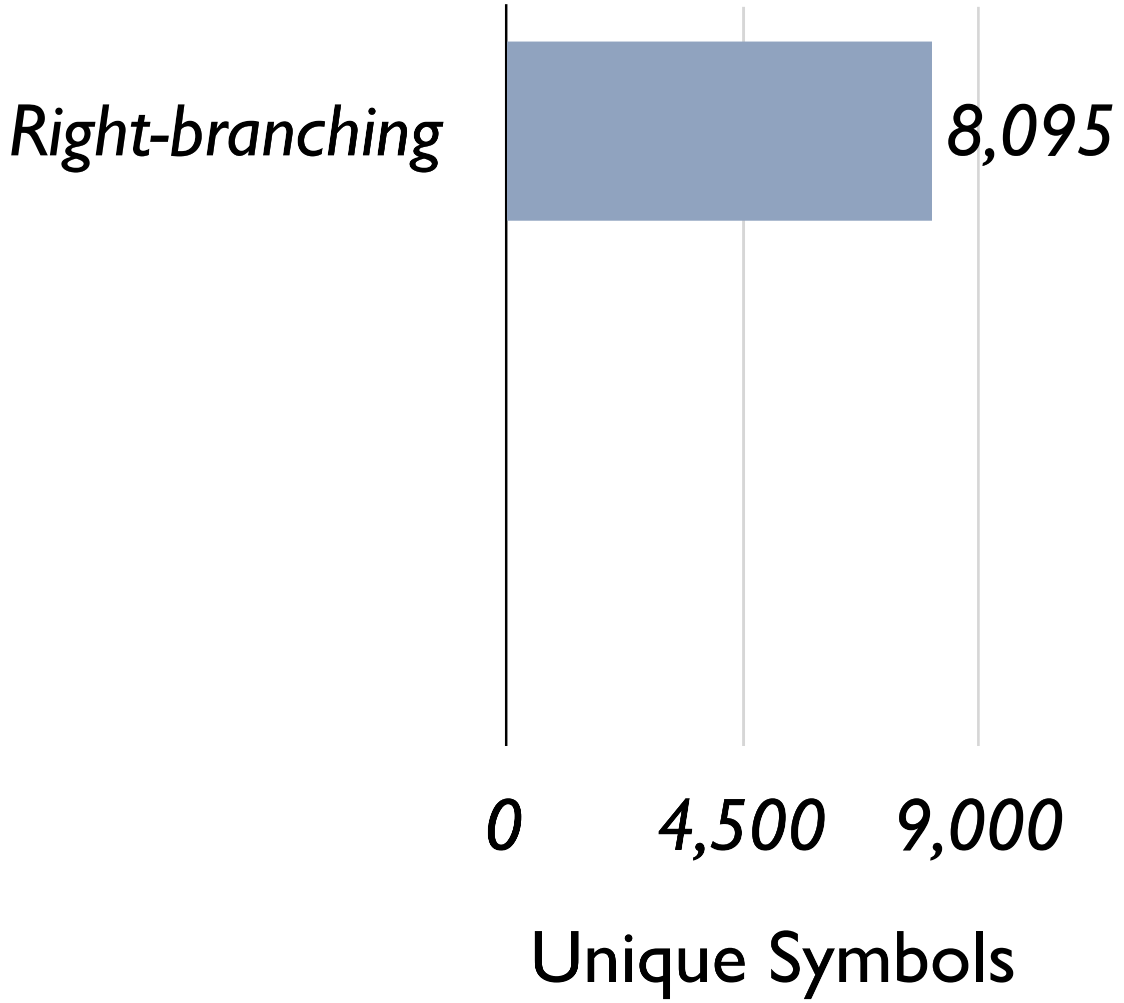

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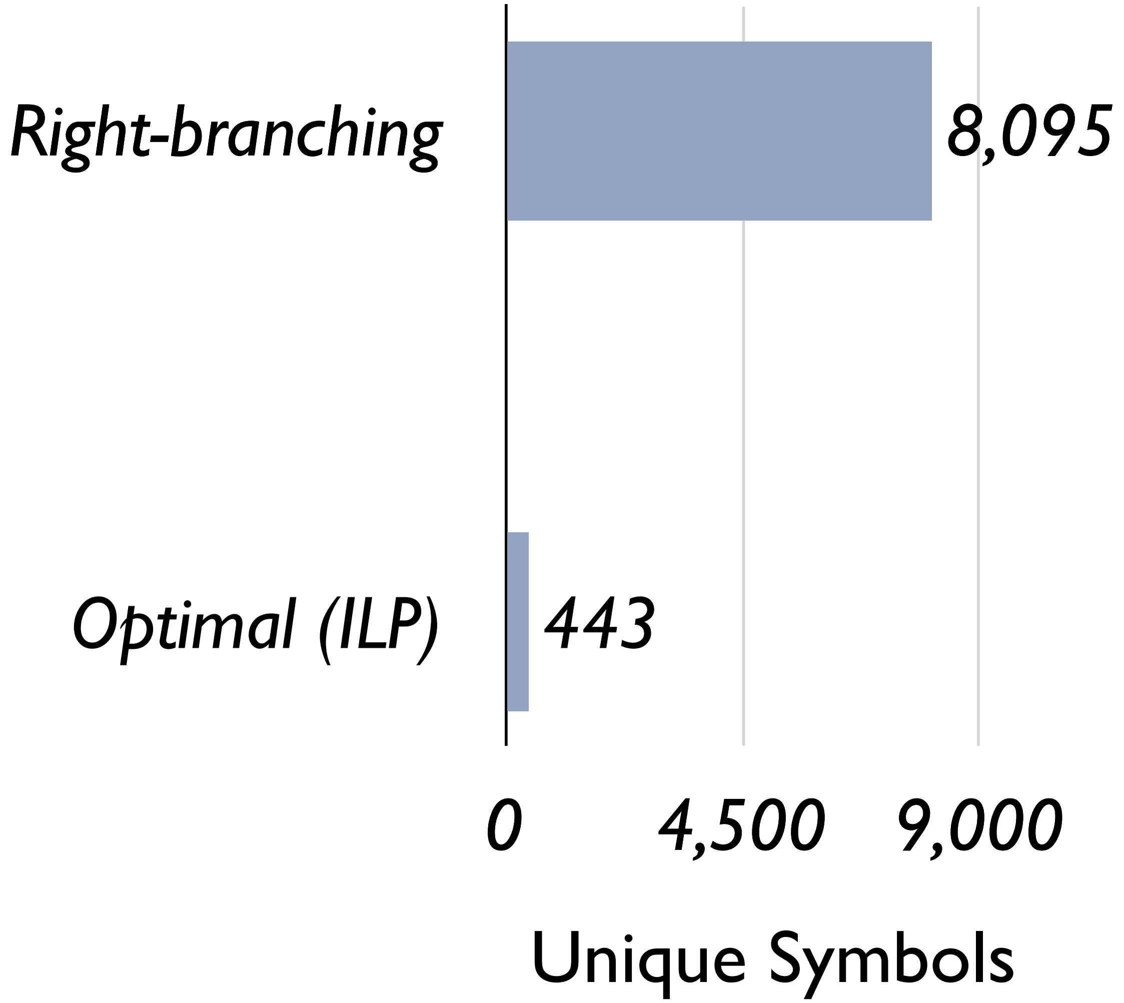

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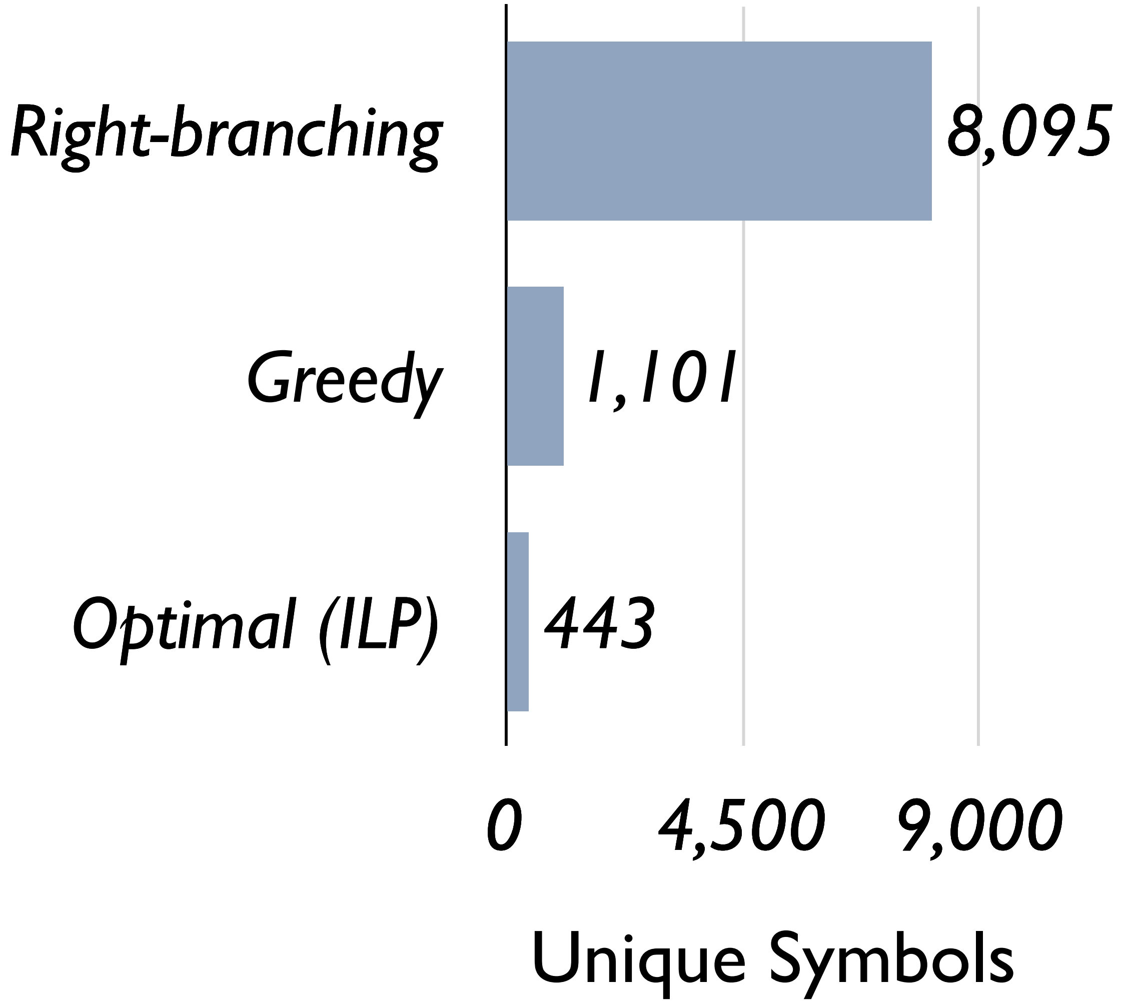

# Subsets of Grammar Symbols

***Problem:*** *Certain large rules always introduce new symbols*

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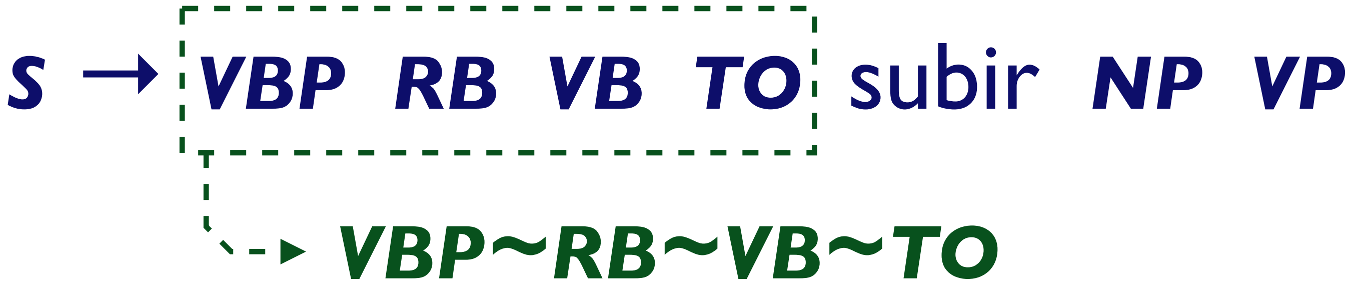

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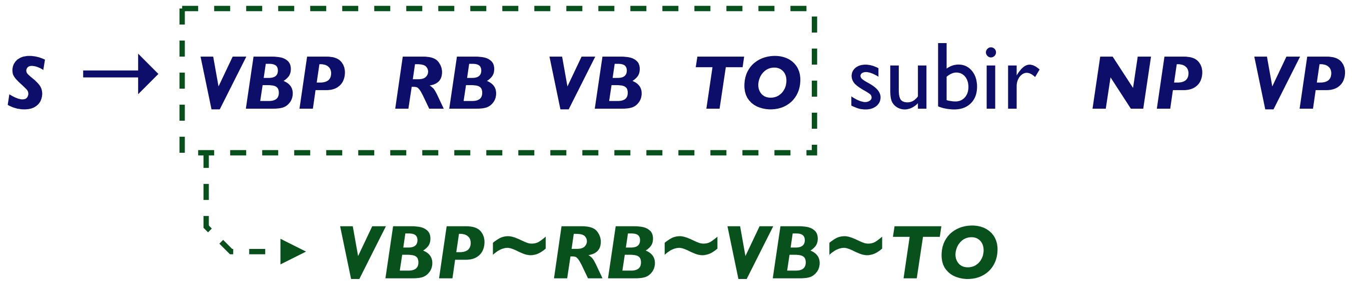

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1. Choose a small subset of high-use symbols
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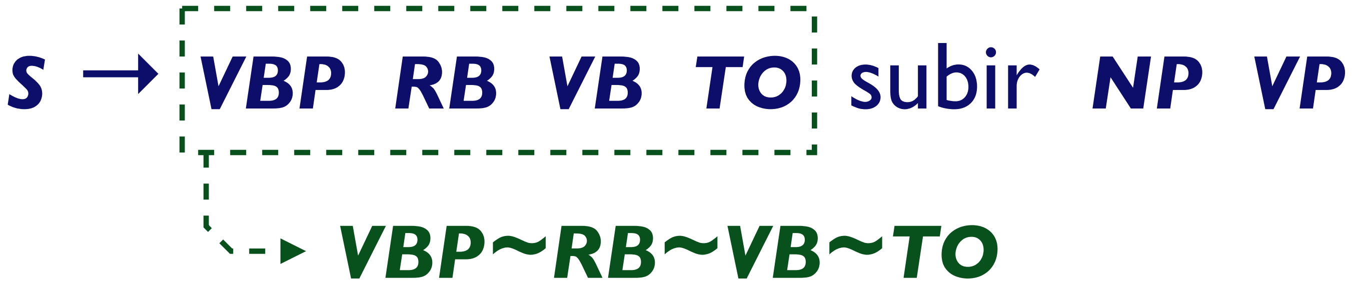

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SPEED
LIMIT

**327**

sentences
per hour

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***Approach:*** *Top-down lazy forest reranking with priority queues (a.k.a., cube growing)*

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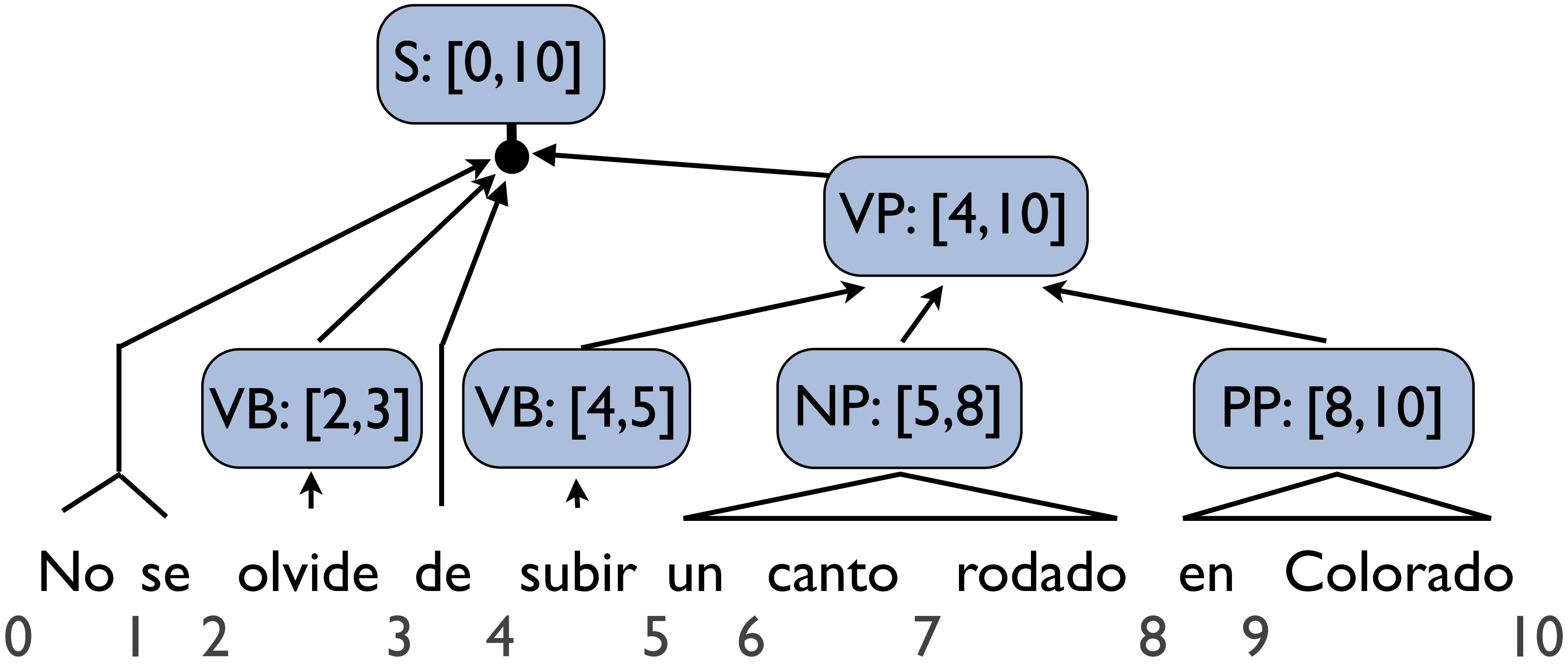

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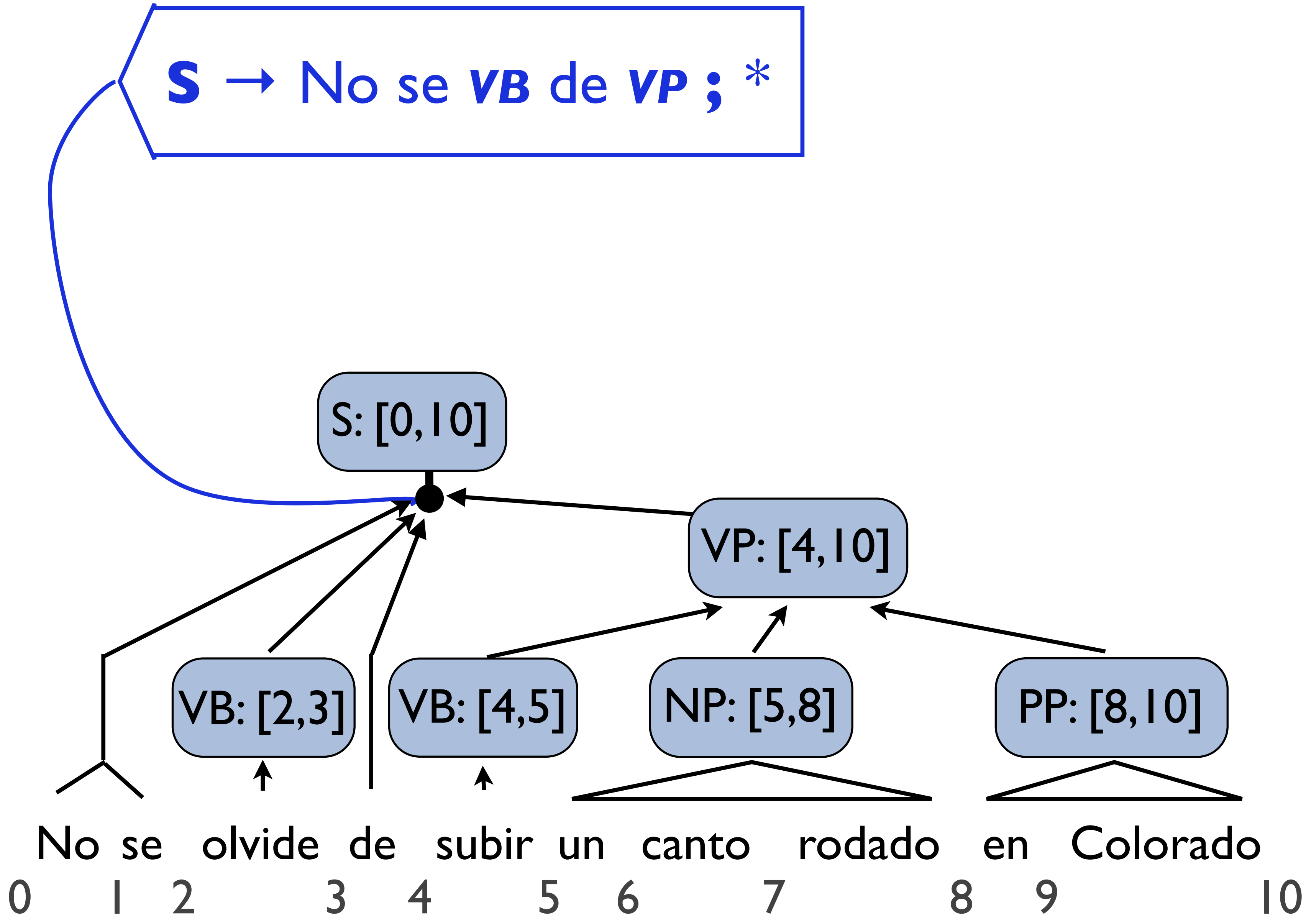

**S** → No se ***VB*** de ***VP*** **;** *
S: [0,10]
VP: [4,10]
VB: [2,3]
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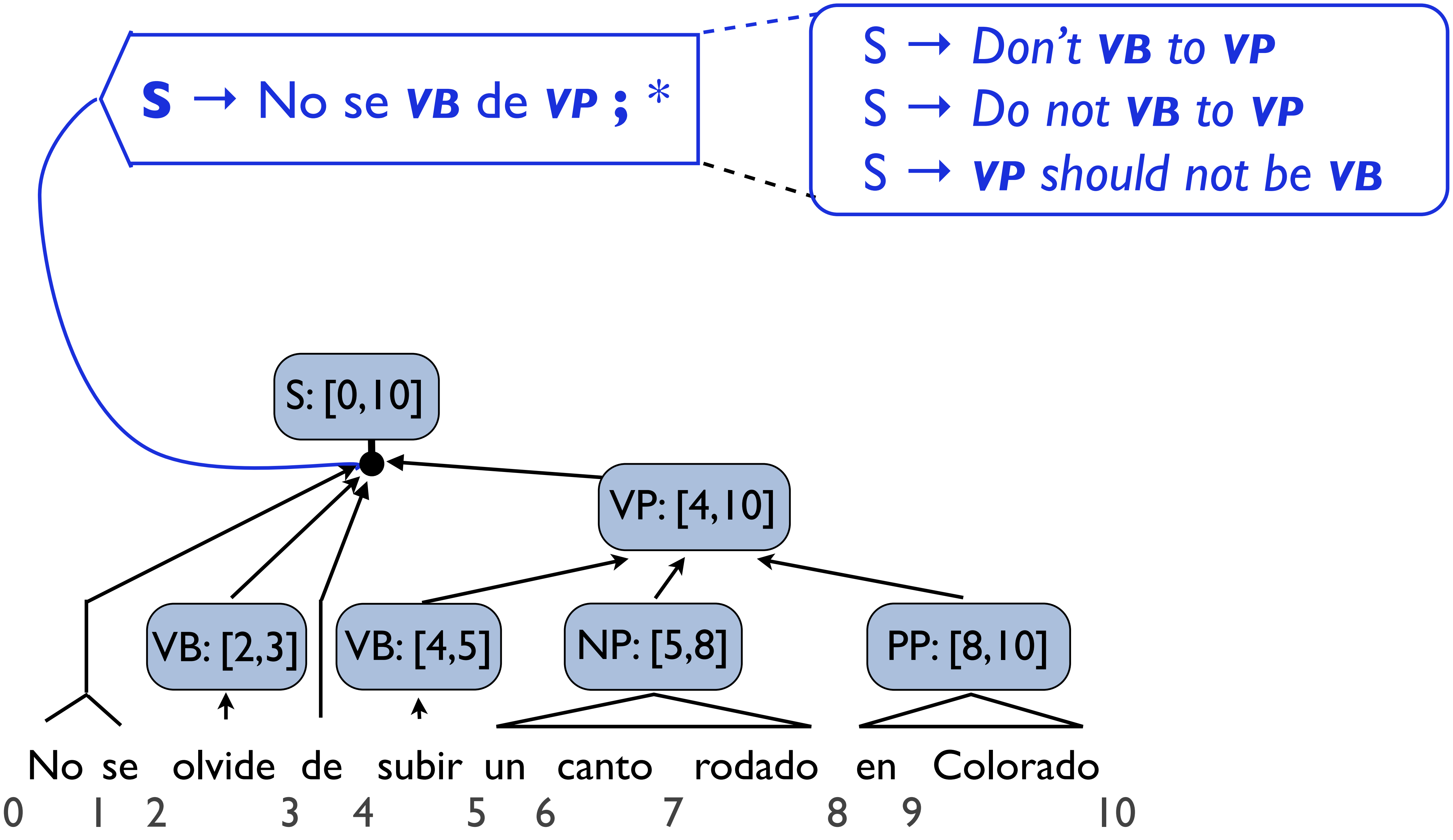

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S → *Do not **VB** to **VP***

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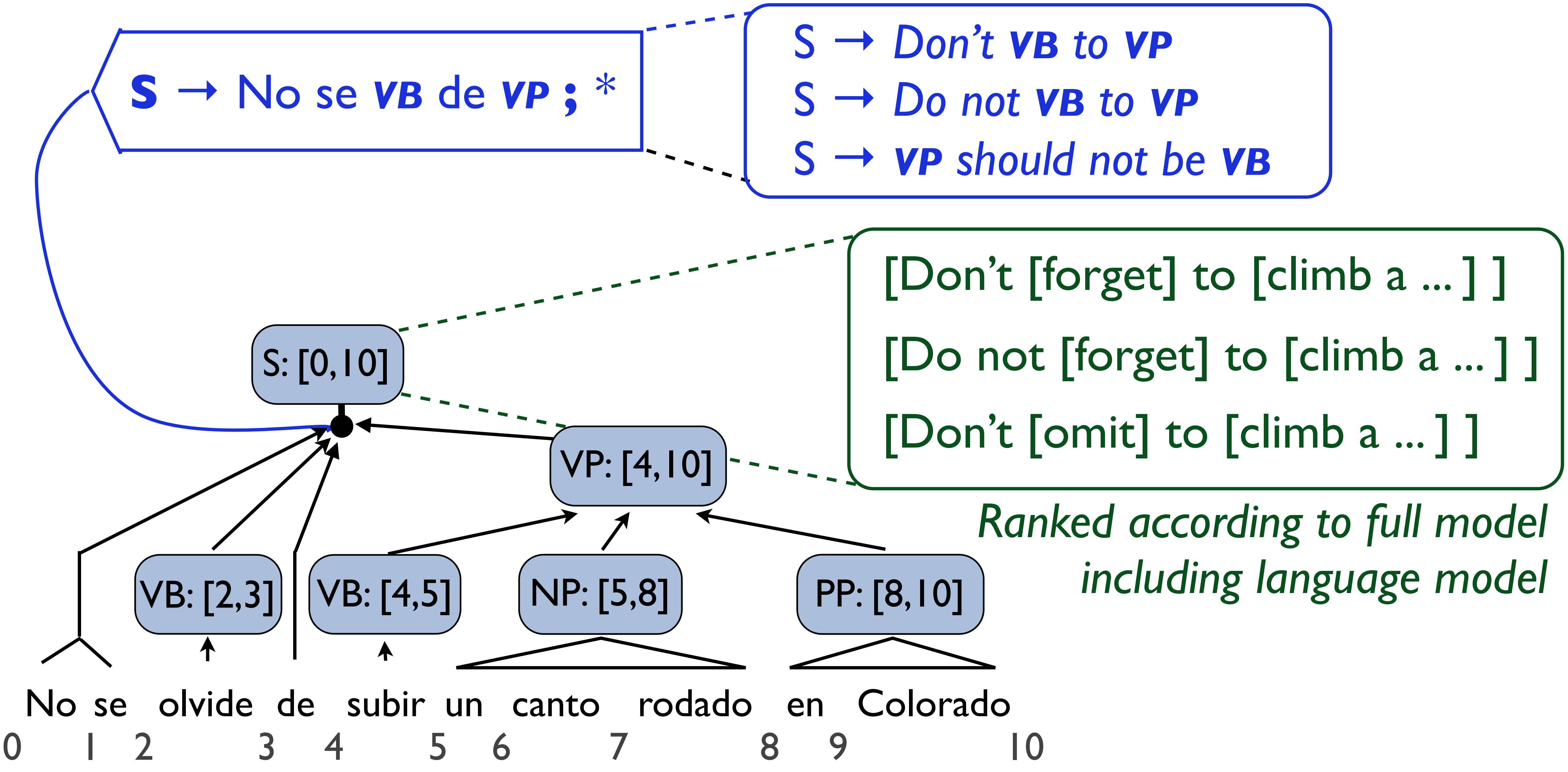

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S → *Don't* ***VB*** *to* ***VP***

S → *Do not* ***VB*** *to* ***VP***

S → ***VP*** *should not be* ***VB***

[Don't [forget] to [climb a ... ] ]

[Do not [forget] to [climb a ... ] ]

[Don't [omit] to [climb a ... ] ]

*Ranked according to full model including language model*

# Coarse-to-Fine LM Integration

**Observation:** *The best translations almost always have a translation model score close to the Viterbi parse score*

**Coarse-to-fine beaming:** *A forest node's beam size is proportional to its posterior under the translation model*

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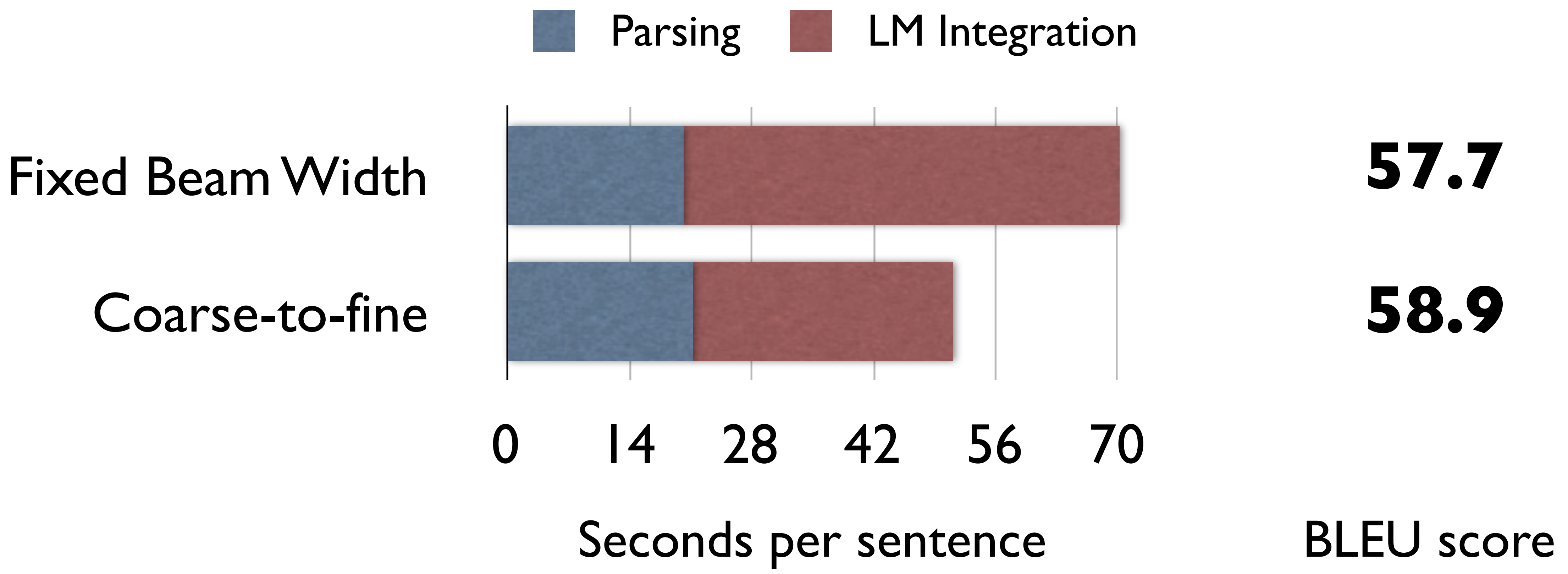

# Summary

- Parsing with the projection of a tree transducer grammar is a non-trivial search problem

- Grammar transformations and algorithmic optimizations decrease parsing time

- Coarse-to-fine search speeds up parsing and makes language model integration more accurate

# Thanks!

Questions?

# The Size of Tree Transducer Grammars

🟦 Rules used     ■ Rules discarded

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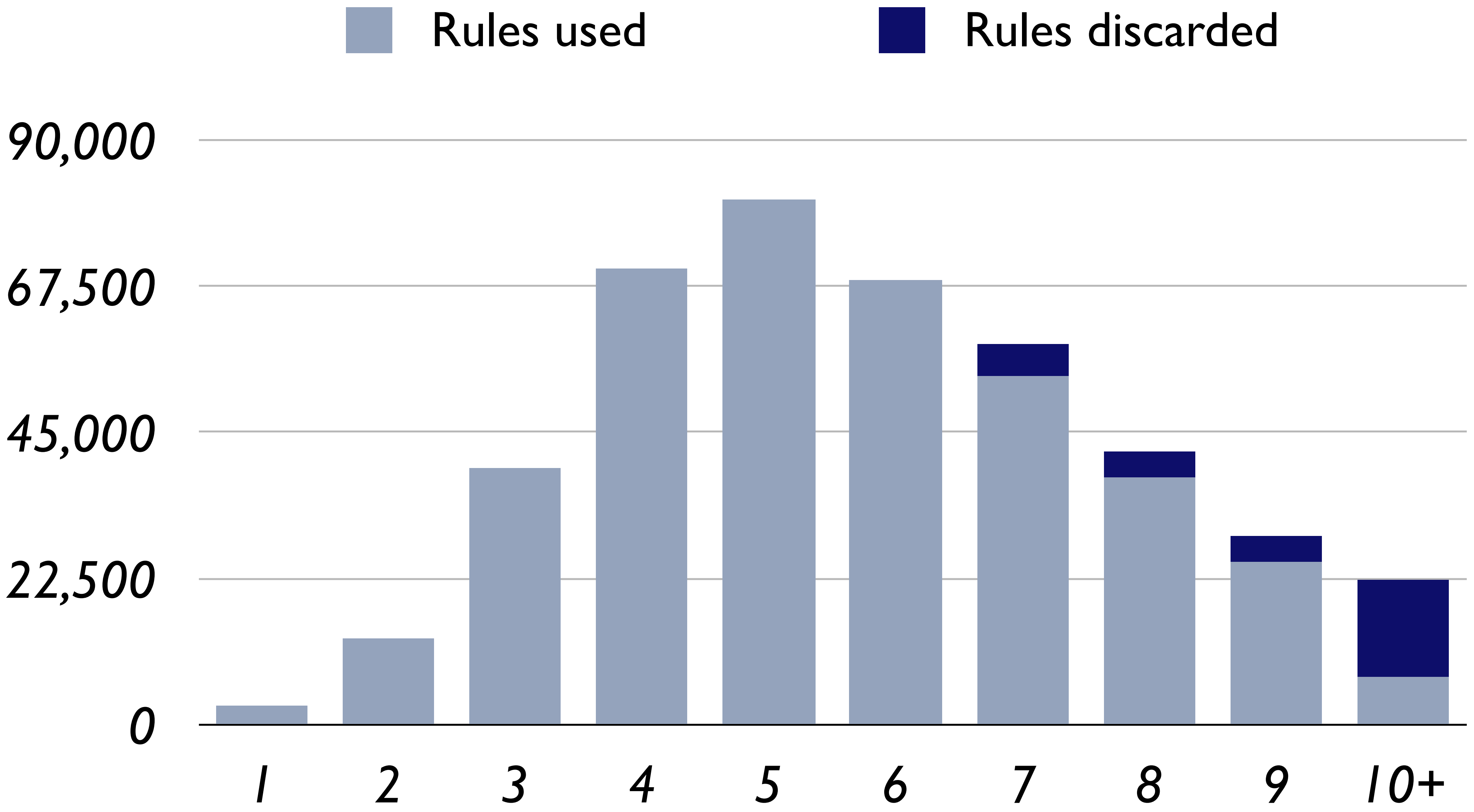
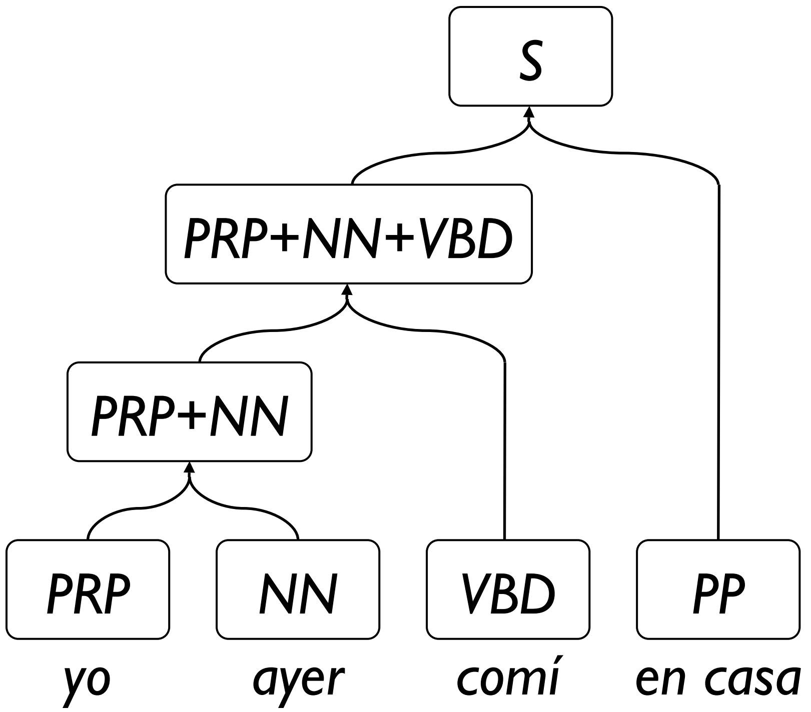


# Rebinarizing for LM Integration (ACL ’09)

## *Parse with ALNF grammar*



S → PRP$_1$ VBD$_3$ NN$_2$ PP$_4$
[[PRP$_1$ NN$_2$] VBD$_3$] PP$_4$

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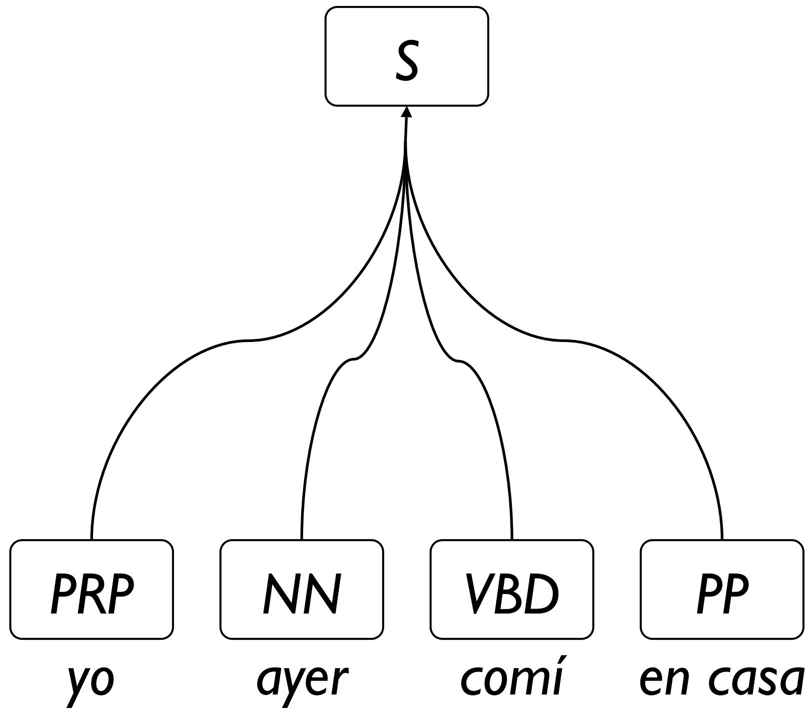
## *Collapse out binarization*



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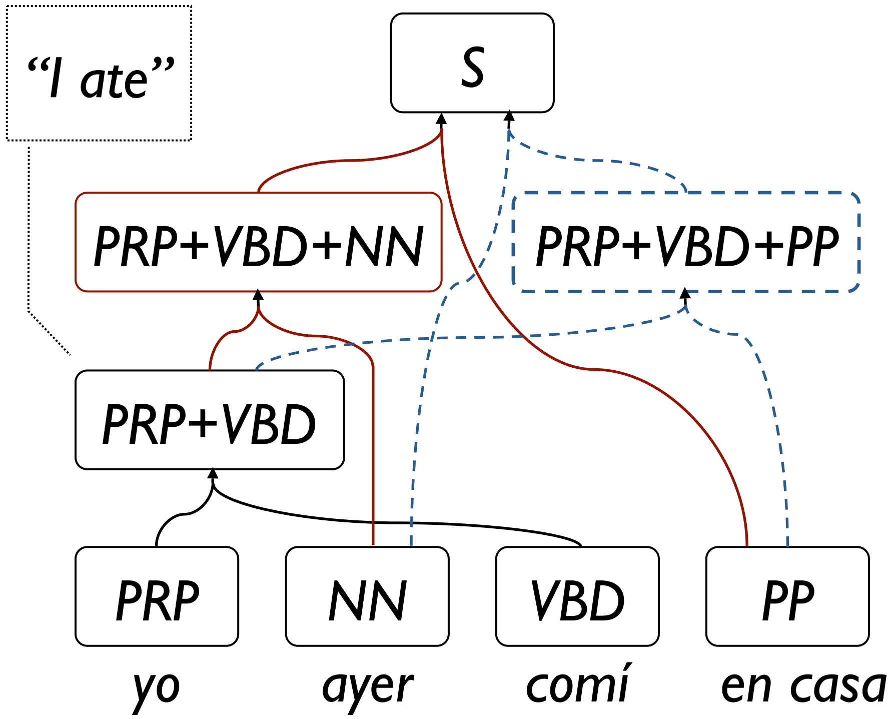

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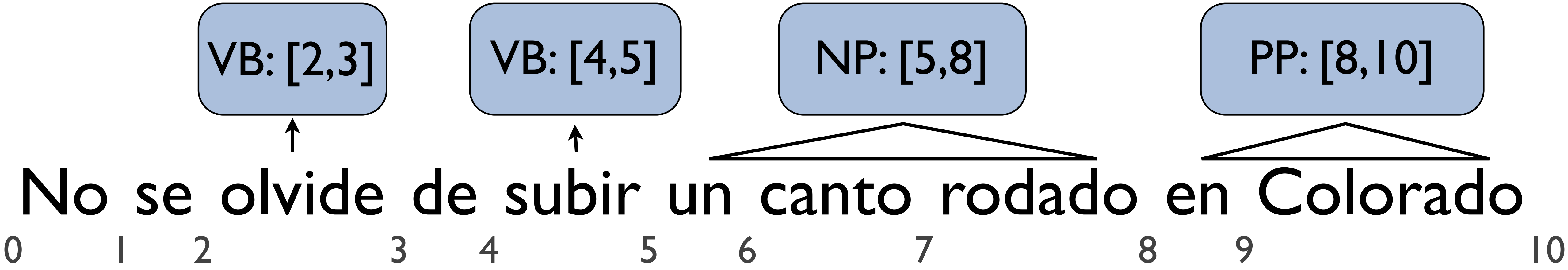
# Multi-Pass Syntactic Decoding

Parse input sentence with source-side grammar projection

Rerank derivations rooted at each state with a language model



VB: [2,3]

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No se olvide de subir un canto rodado en Colorado

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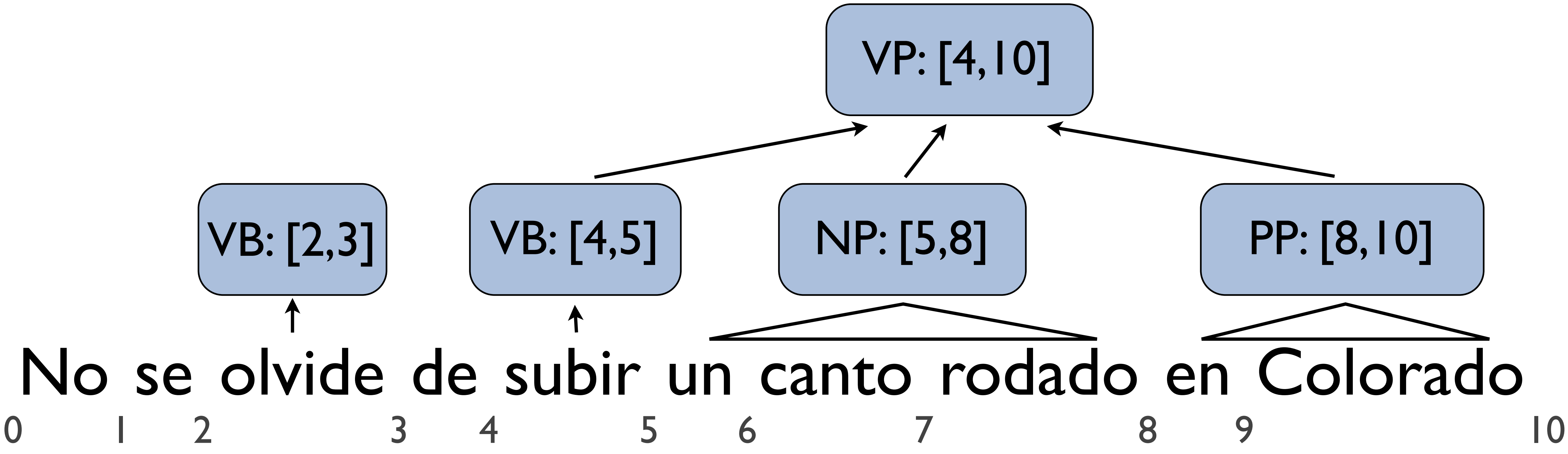

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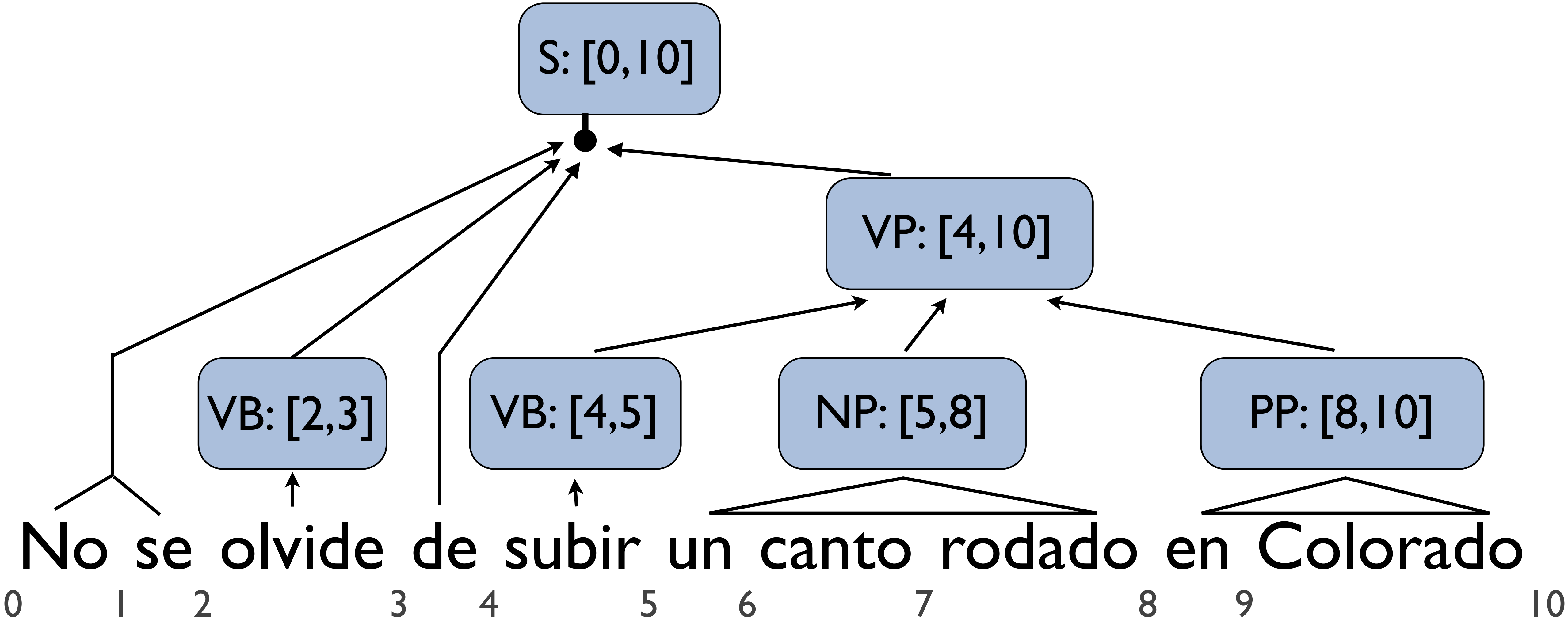

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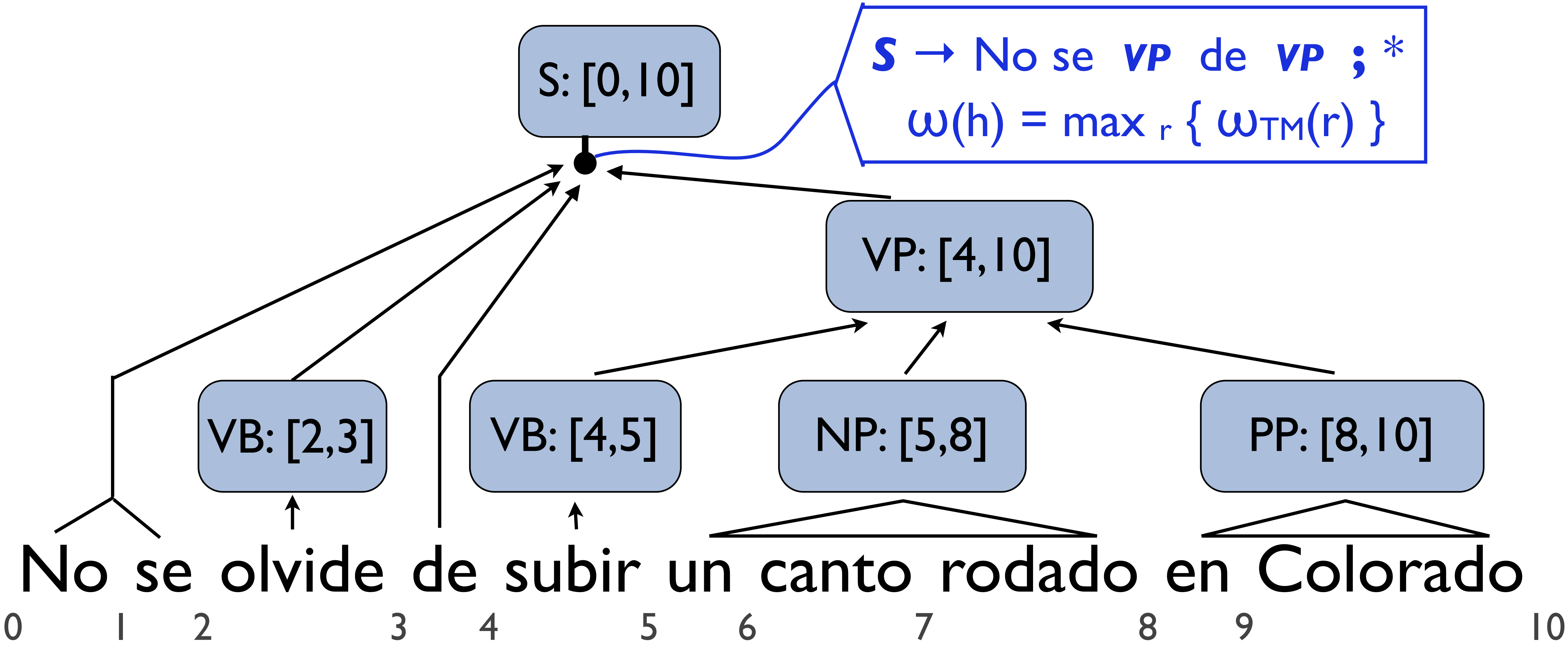

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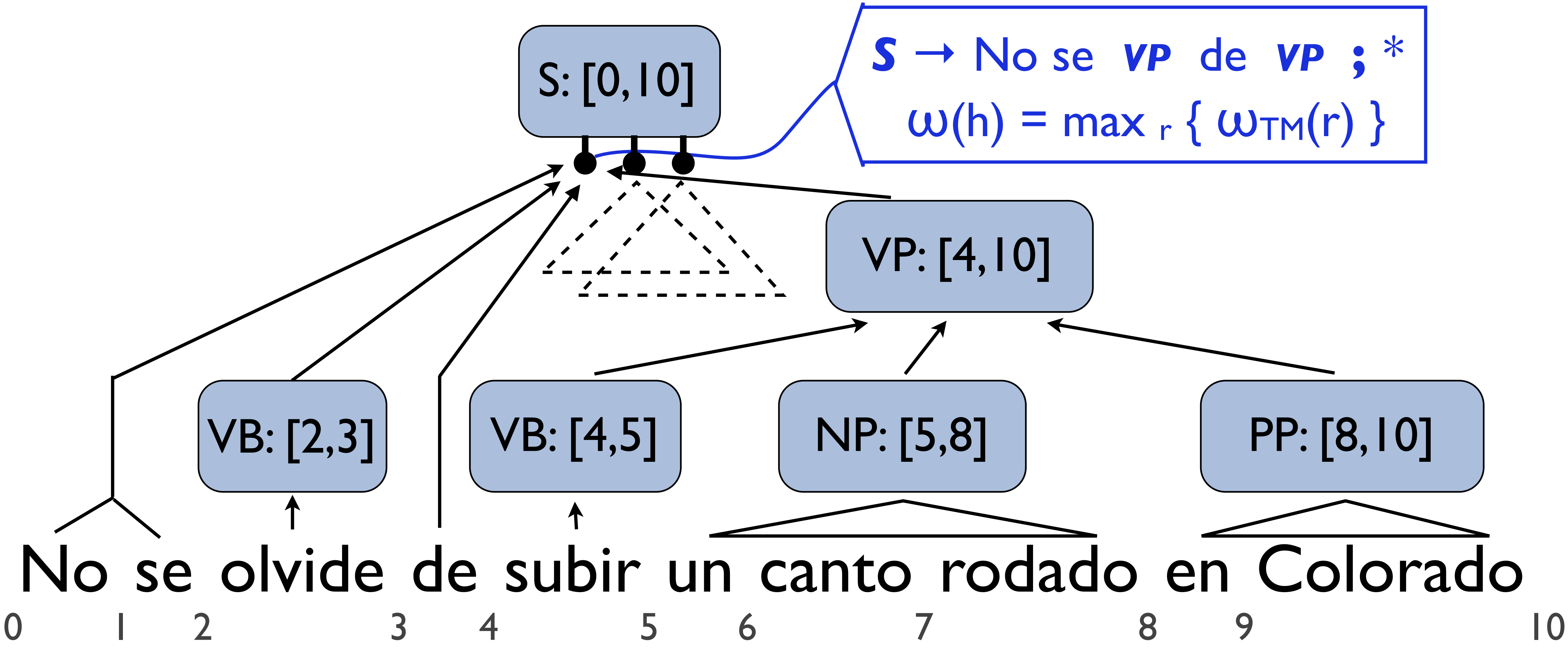

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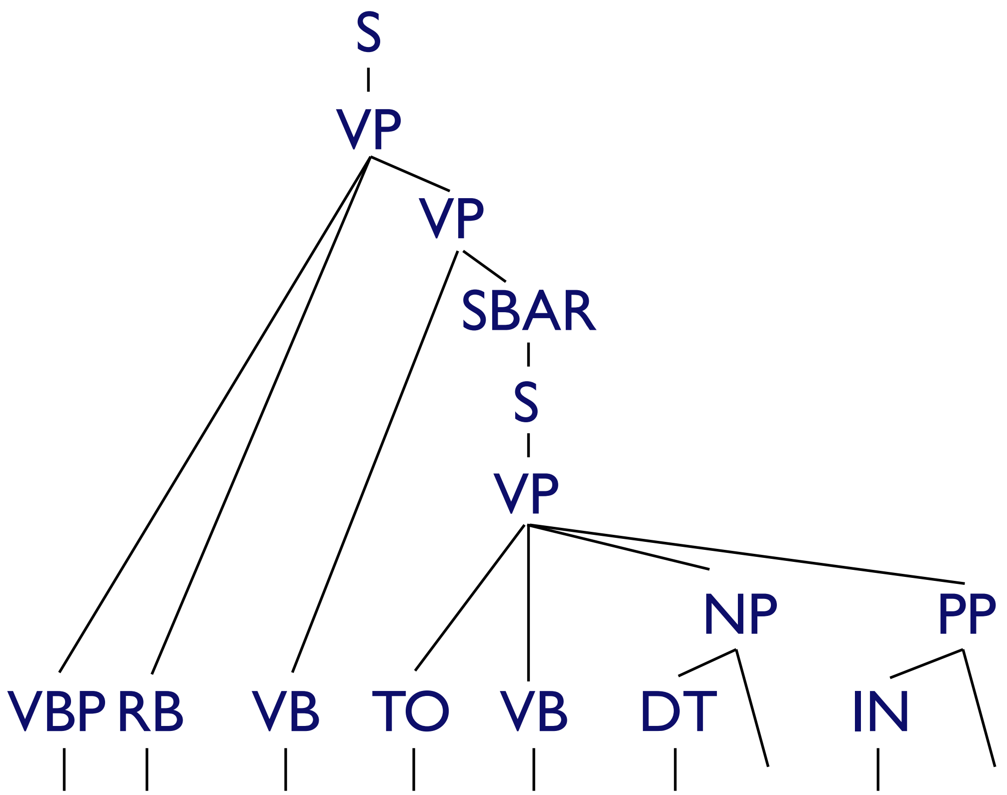
# Tree Transducer Grammars

No se olvide de subir un canto rodado en Colorado

**Rules**



No se olvide de subir un $NN_1$ en $NNP_2$ **;** *Don't forget to climb a* $NN_1$ in $NNP_2$

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No se olvide de subir un canto rodado en Colorado

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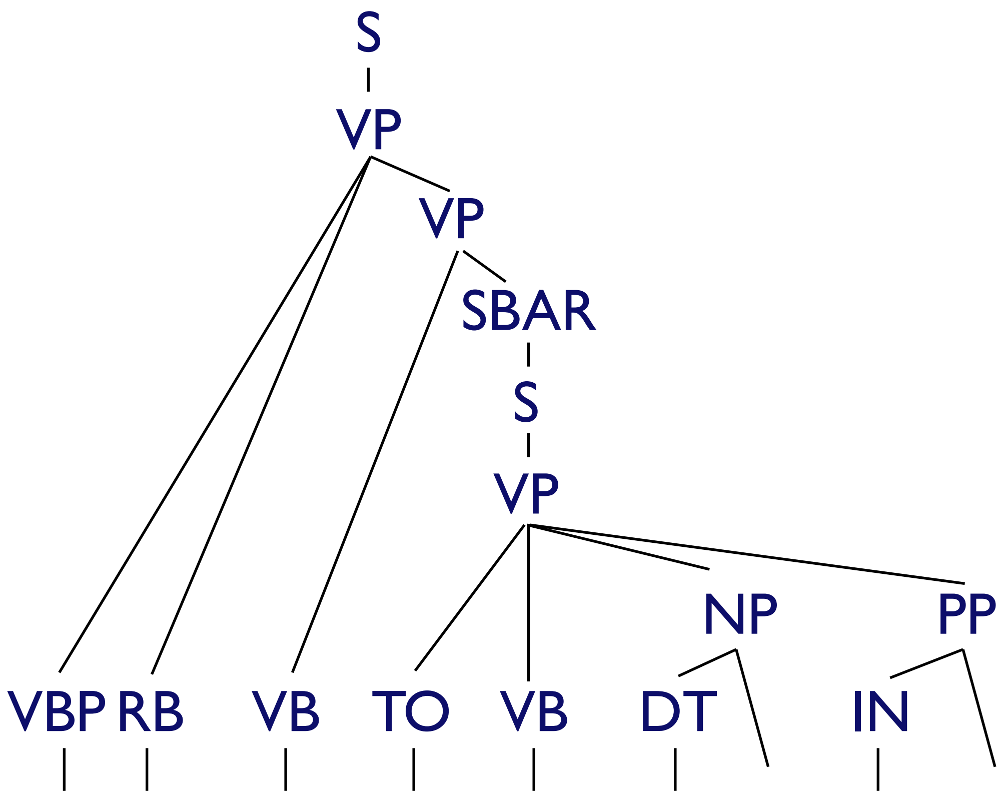
NN

canto rodado ; *boulder*

NNP

Colorado ; *Colorado*



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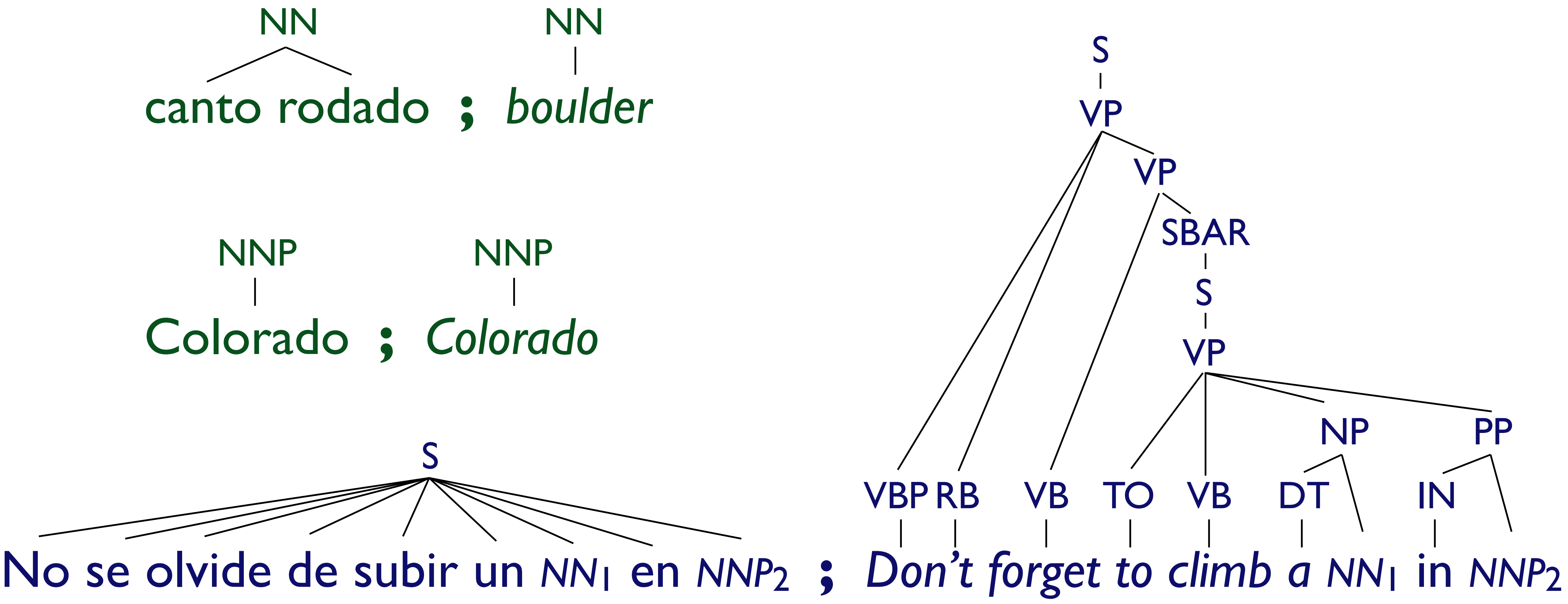

NN → canto rodado ; NN → *boulder*

NNP → Colorado ; NNP → *Colorado*

S → No se olvide de subir un *$NN_1$* en *$NNP_2$* ; S(VP(VBP RB VP(VB SBAR(S(VP(TO VB NP(DT *$NN_1$*) PP(IN *$NNP_2$*))))))) → *Don't forget to climb a $NN_1$* in *$NNP_2$*