Algorithms for NLP

Machine Translation IV

Taylor Berg-Kirkpatrick – CMU

Slides: Dan Klein, David Hall – UC Berkeley

Announcements

- Project 3 due date postponed
  - Now Monday 11/14 at 11:59pm
- Will hold office hours tomorrow
- Recitation will be project office hours

Project 1 best.jar!

- Best BLEU:
  - Shruti Rijhwani – 25.045 (D = 0.9)
  - Yulun Du – 25.038 (D = 0.9)
- Best memory consumption:
  - Harsh Jhamtani – 683M (packed sorted table)
  - Pengcheng Yin – 745M (rank tables)
- Best running time: (still being computed)
  - Smart caching
  - Murmur hashing

Translating with Tree Transducers

Input **Output**

lo haré de muy buen grado .

Grammar

Translating with Tree Transducers

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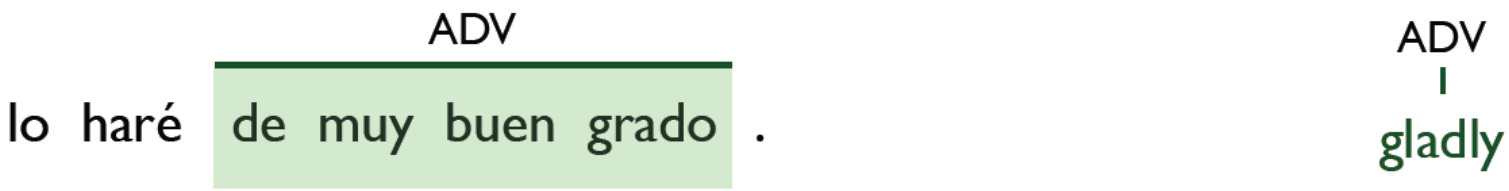
lo haré de muy buen grado .

Grammar

ADV → ⟨ de muy buen grado ; gladly ⟩

Translating with Tree Transducers

Input **Output**



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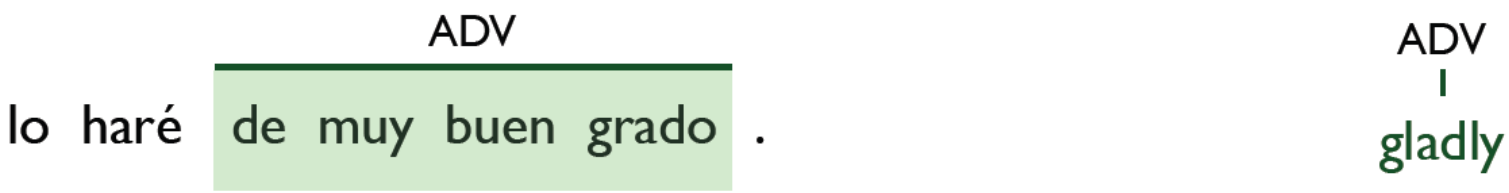

Grammar

S → ⟨ lo haré ADV . ; I will do it ADV . ⟩

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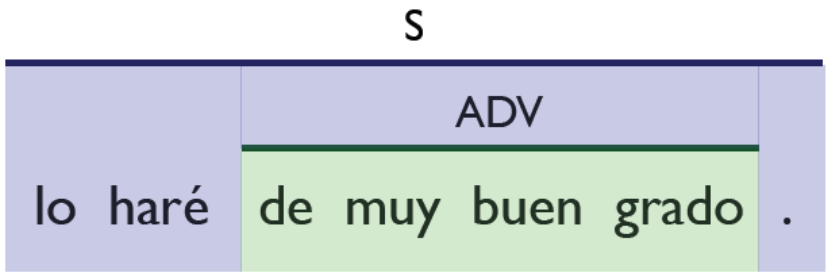

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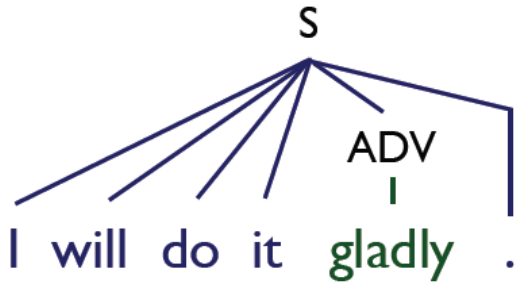

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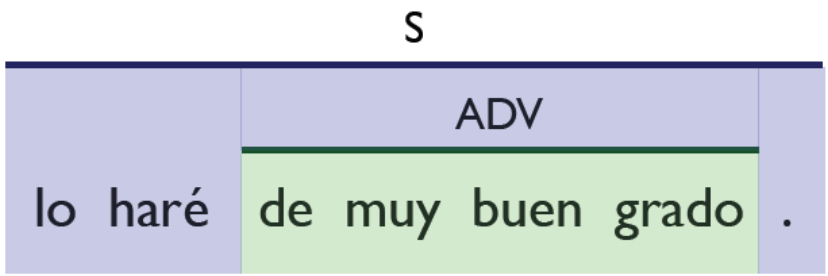

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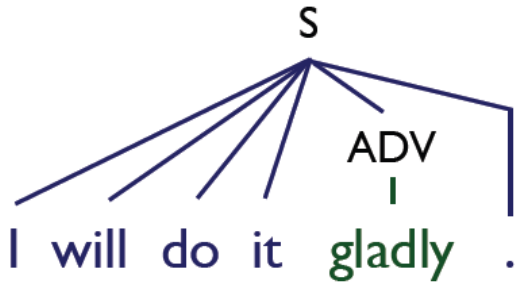

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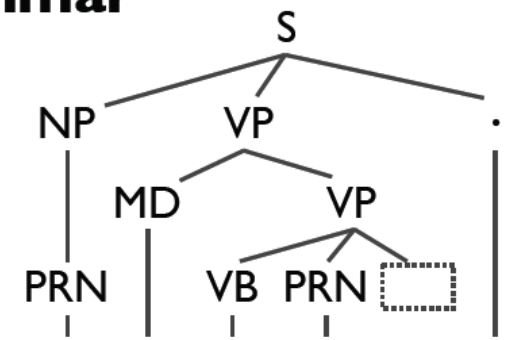

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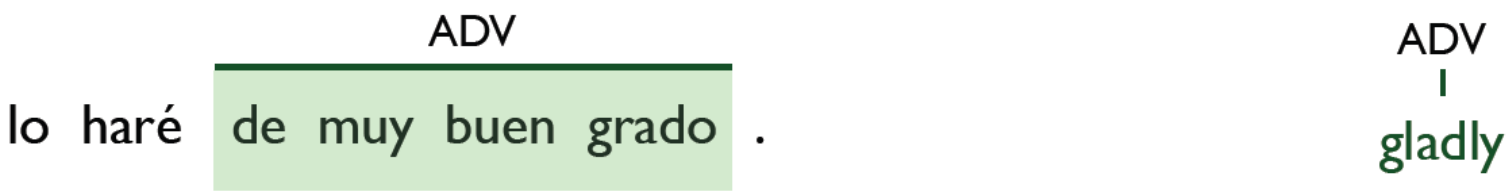

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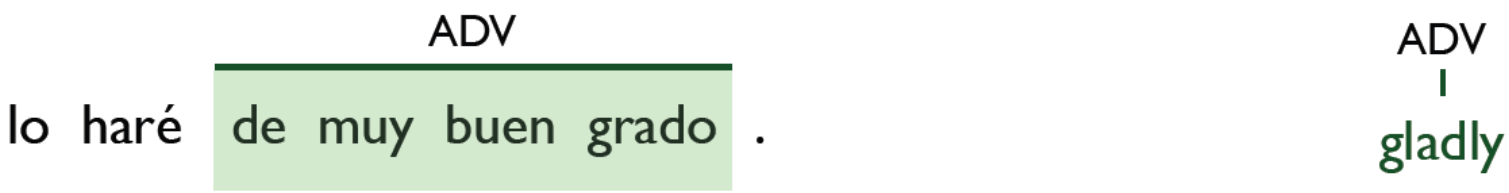

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VP → ⟨ lo haré ADV ; will do it ADV ⟩

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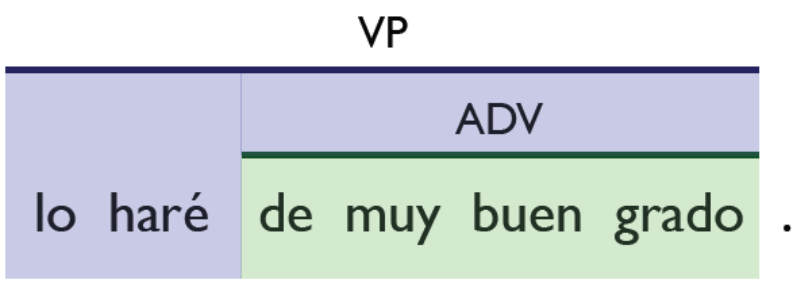

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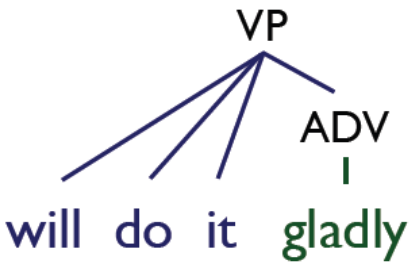

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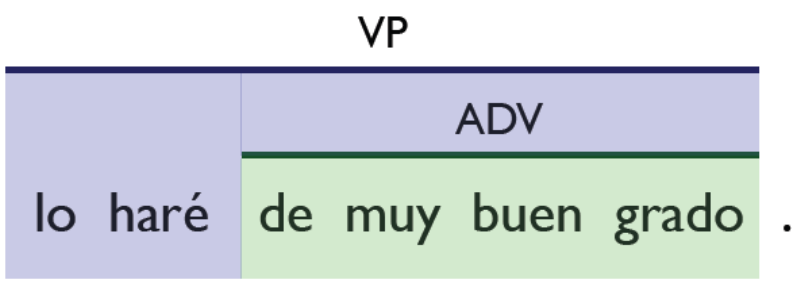

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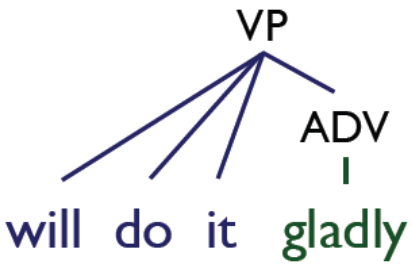

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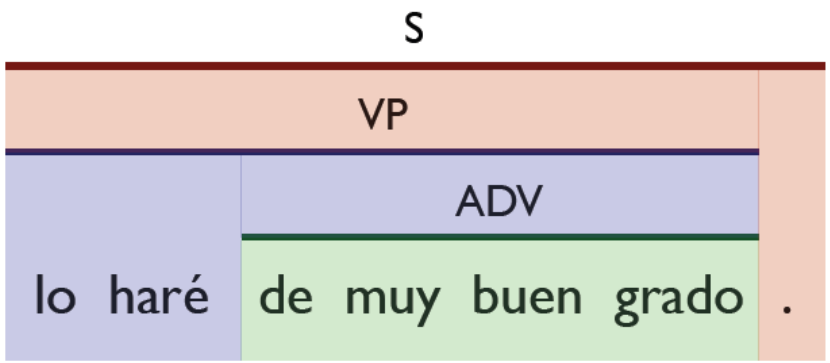

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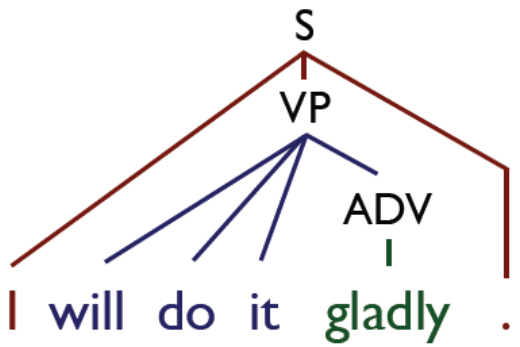

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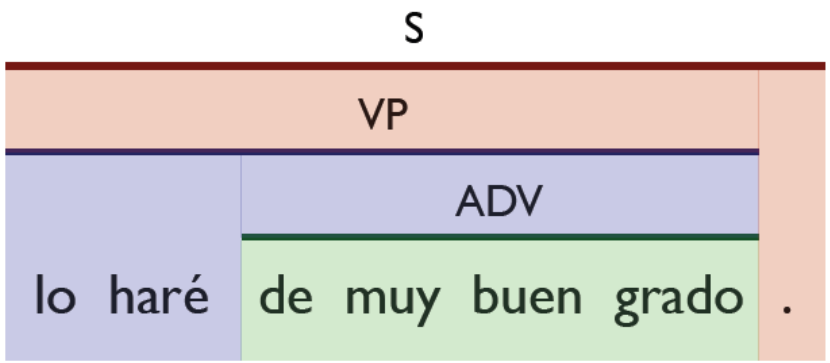

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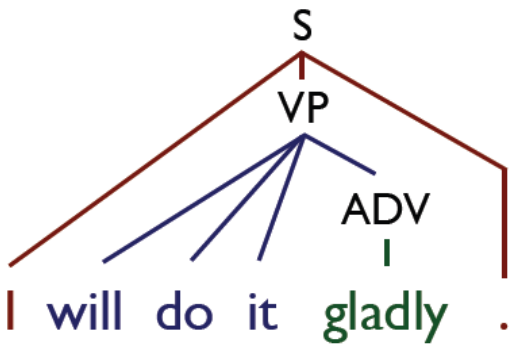


Grammar

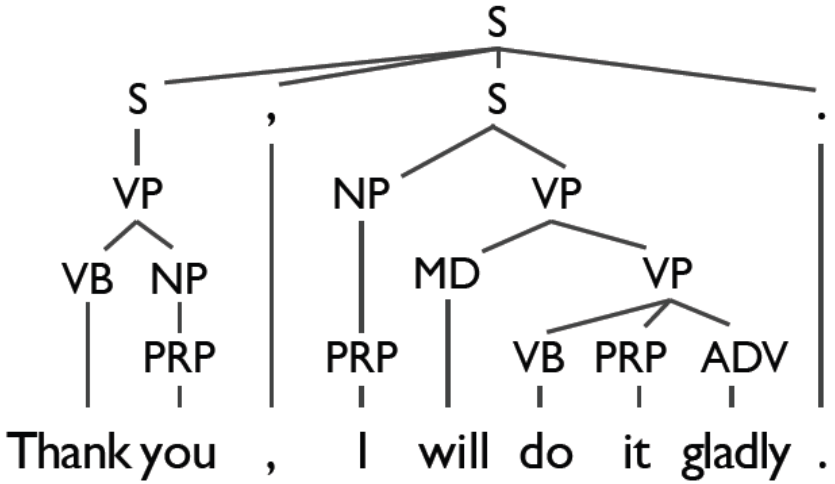
S → ⟨ VP . ; I VP . ⟩ **OR** S → ⟨ VP . ; you VP . ⟩

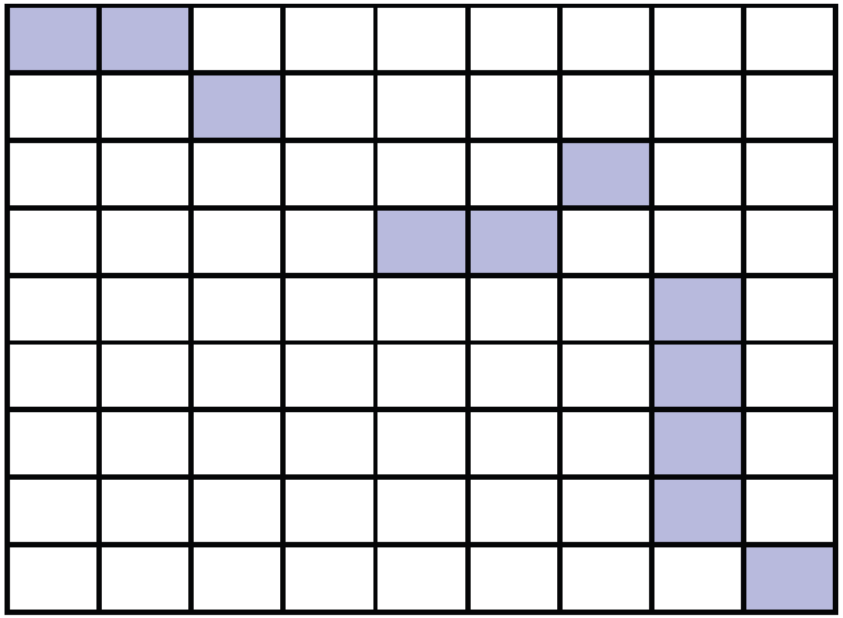
VP → ⟨ lo haré ADV ; will do it ADV ⟩

S → ⟨ lo haré ADV . ; I will do it ADV . ⟩

ADV → ⟨ de muy buen grado ; gladly ⟩

Learning Grammars for Translation





Grammar Rules

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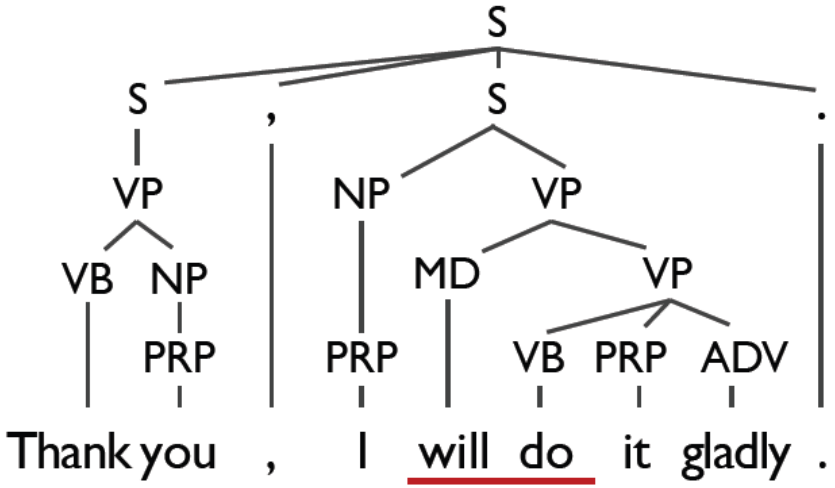

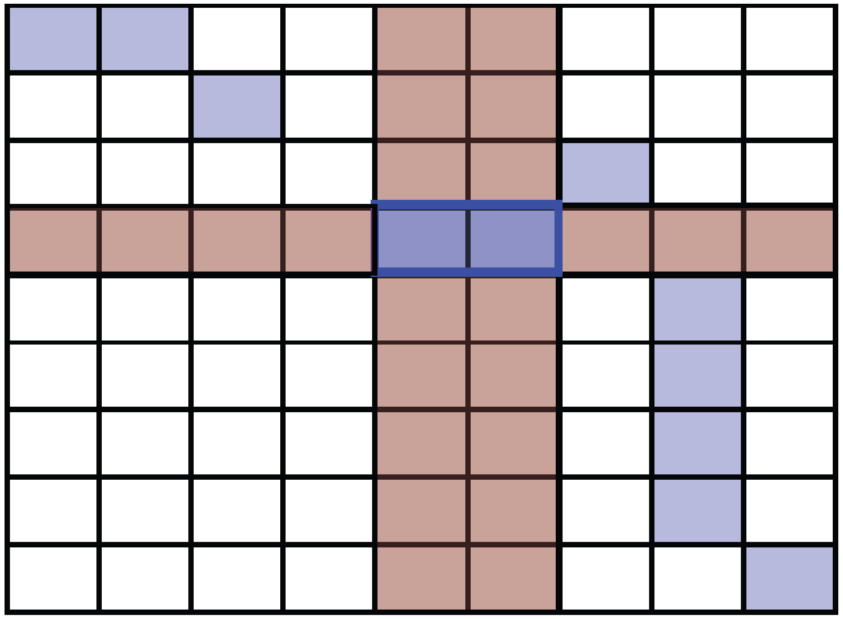

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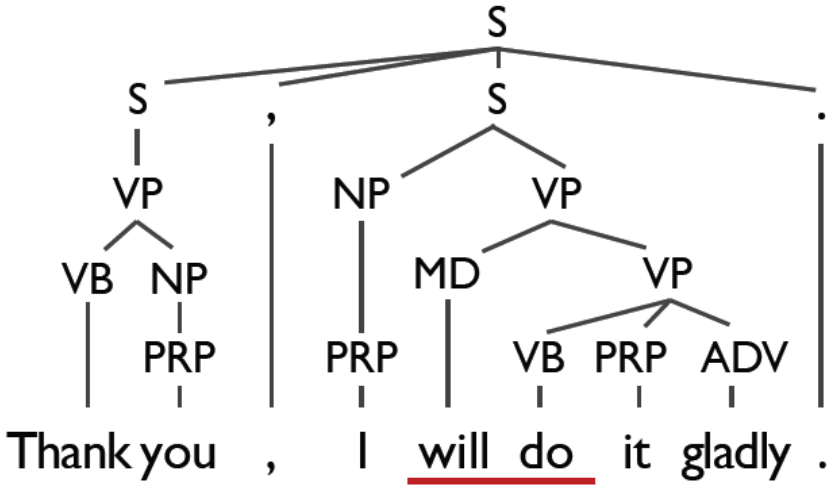

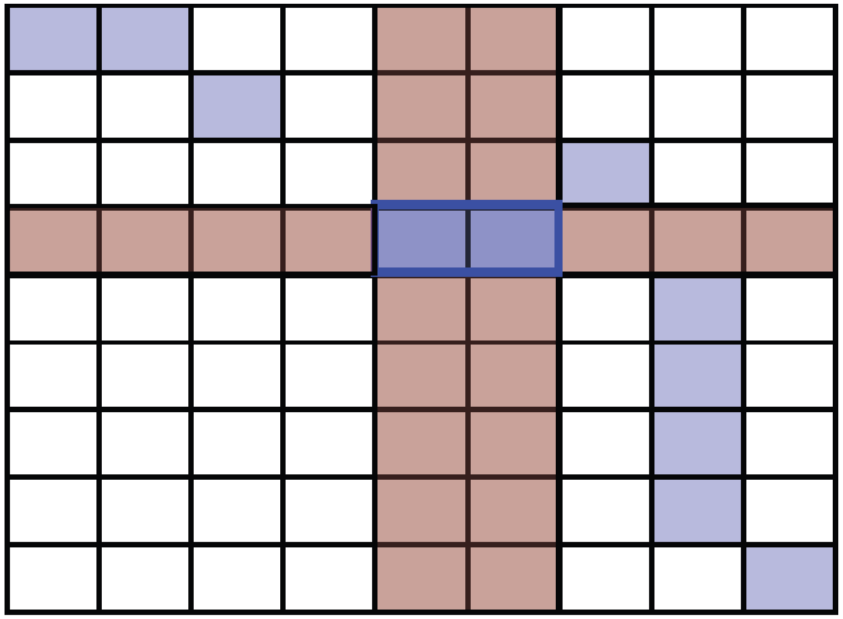

Grammar Rules

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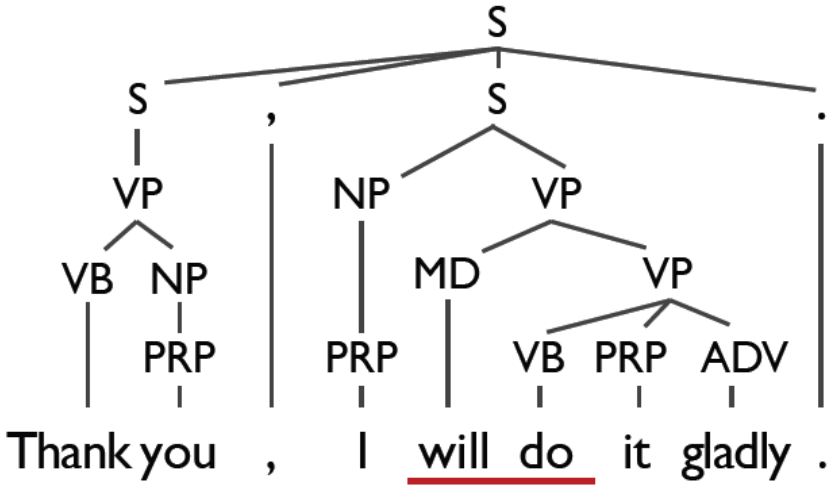

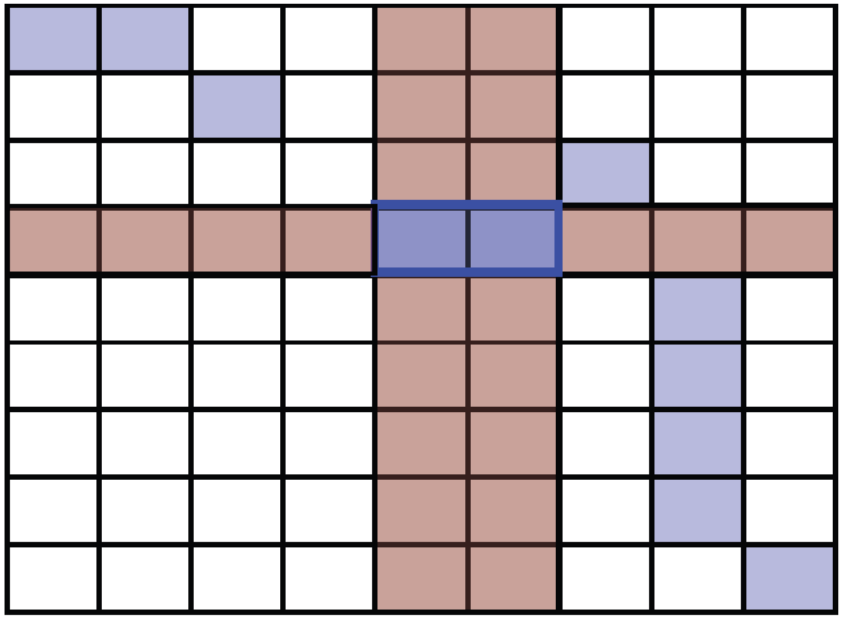

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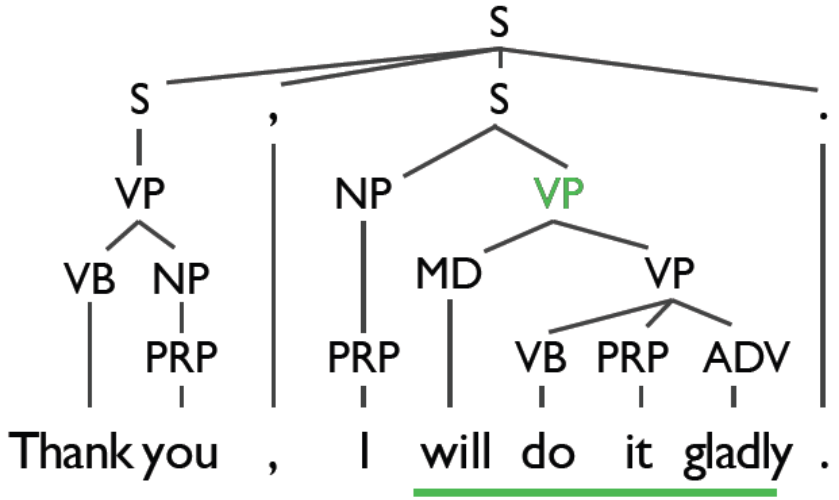

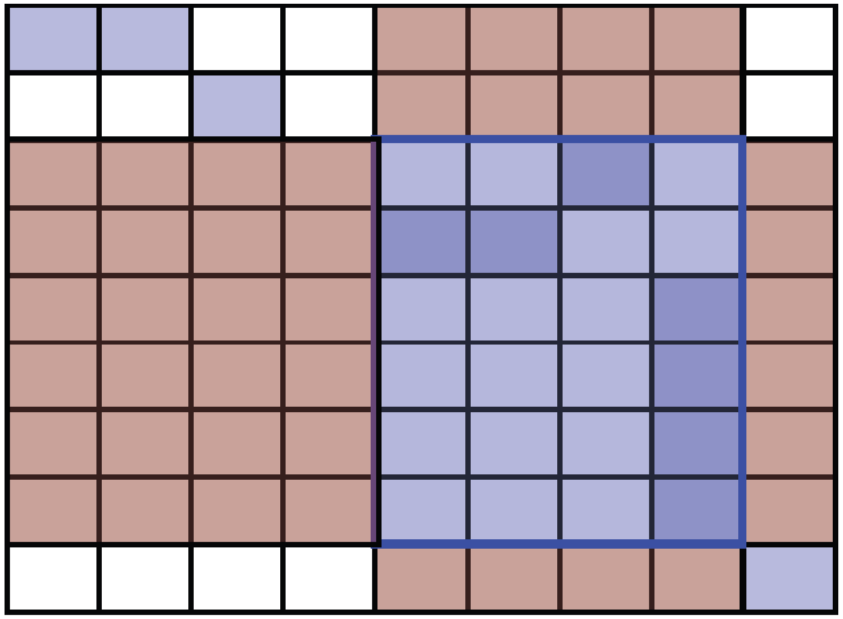

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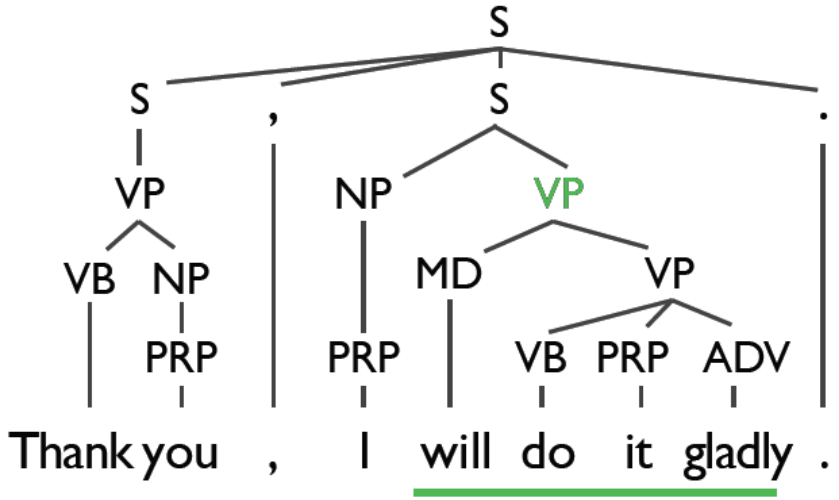

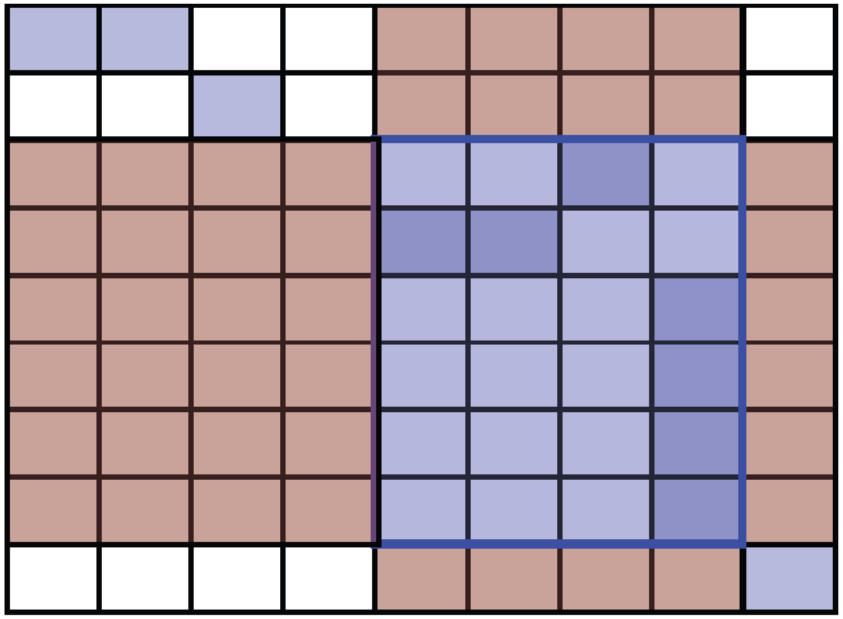

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Grammar Rules

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VP →

⟨lo haré de ... grado ;
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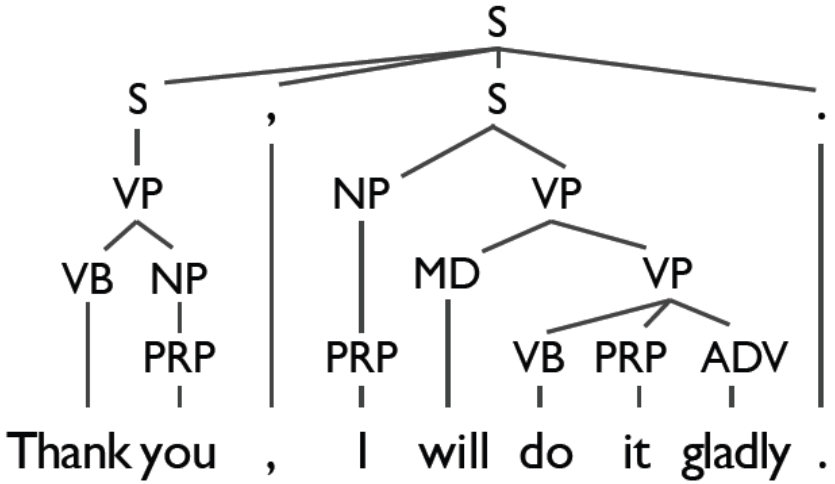

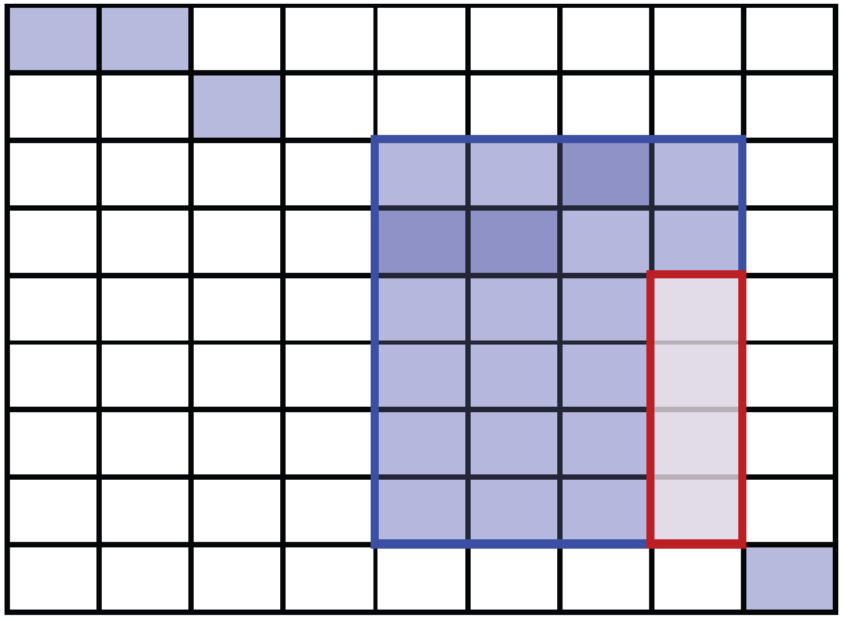

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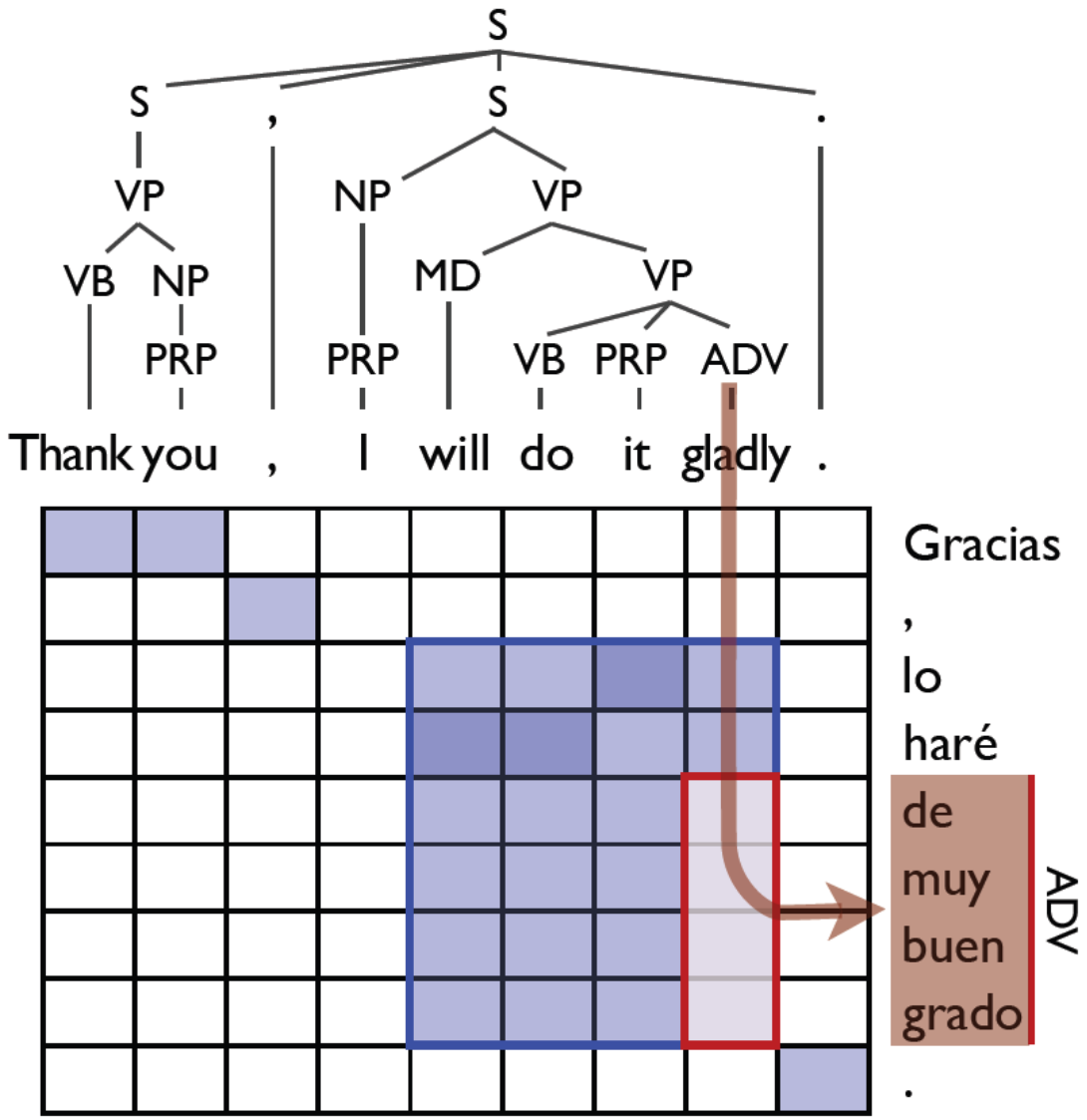

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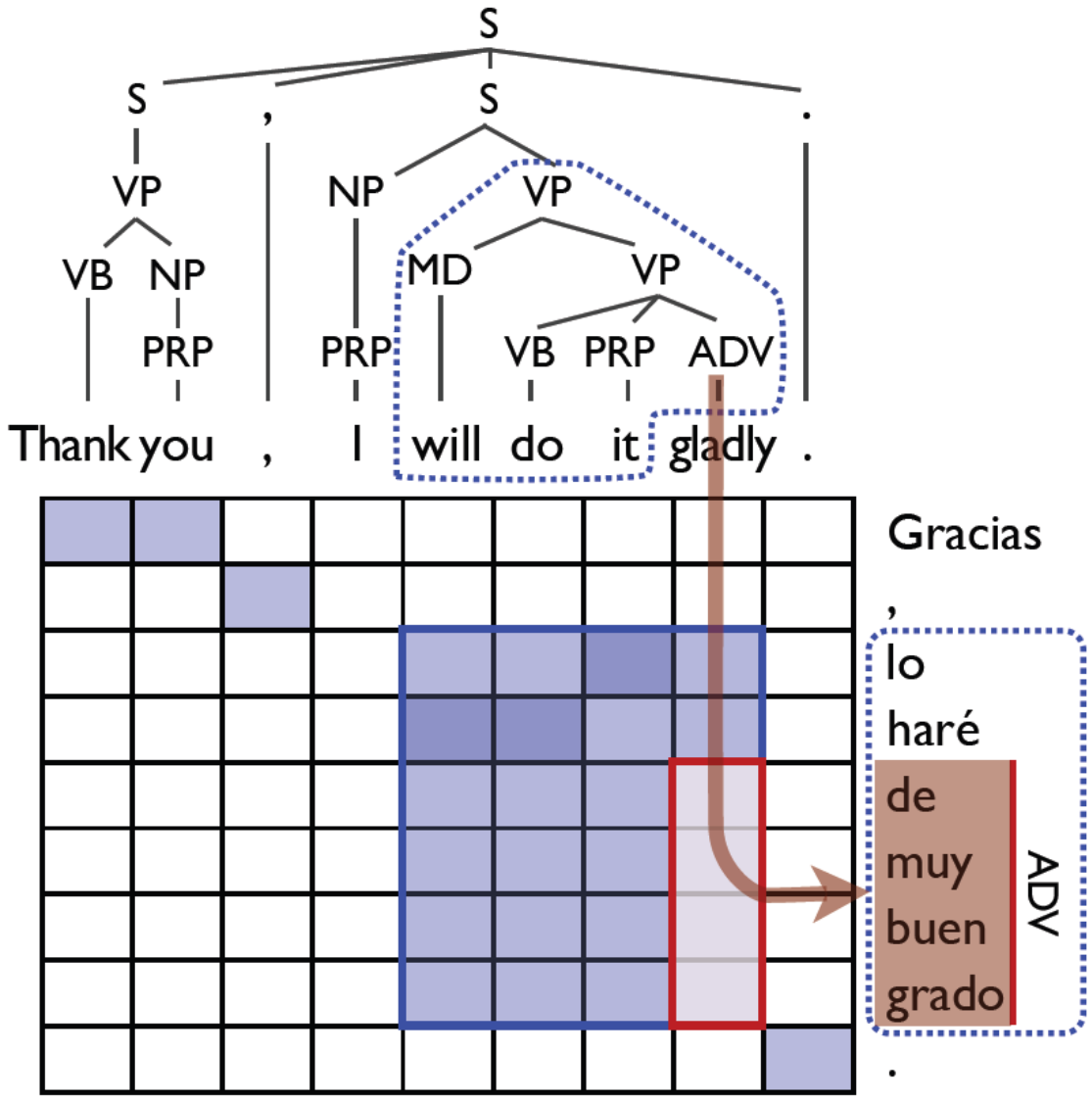

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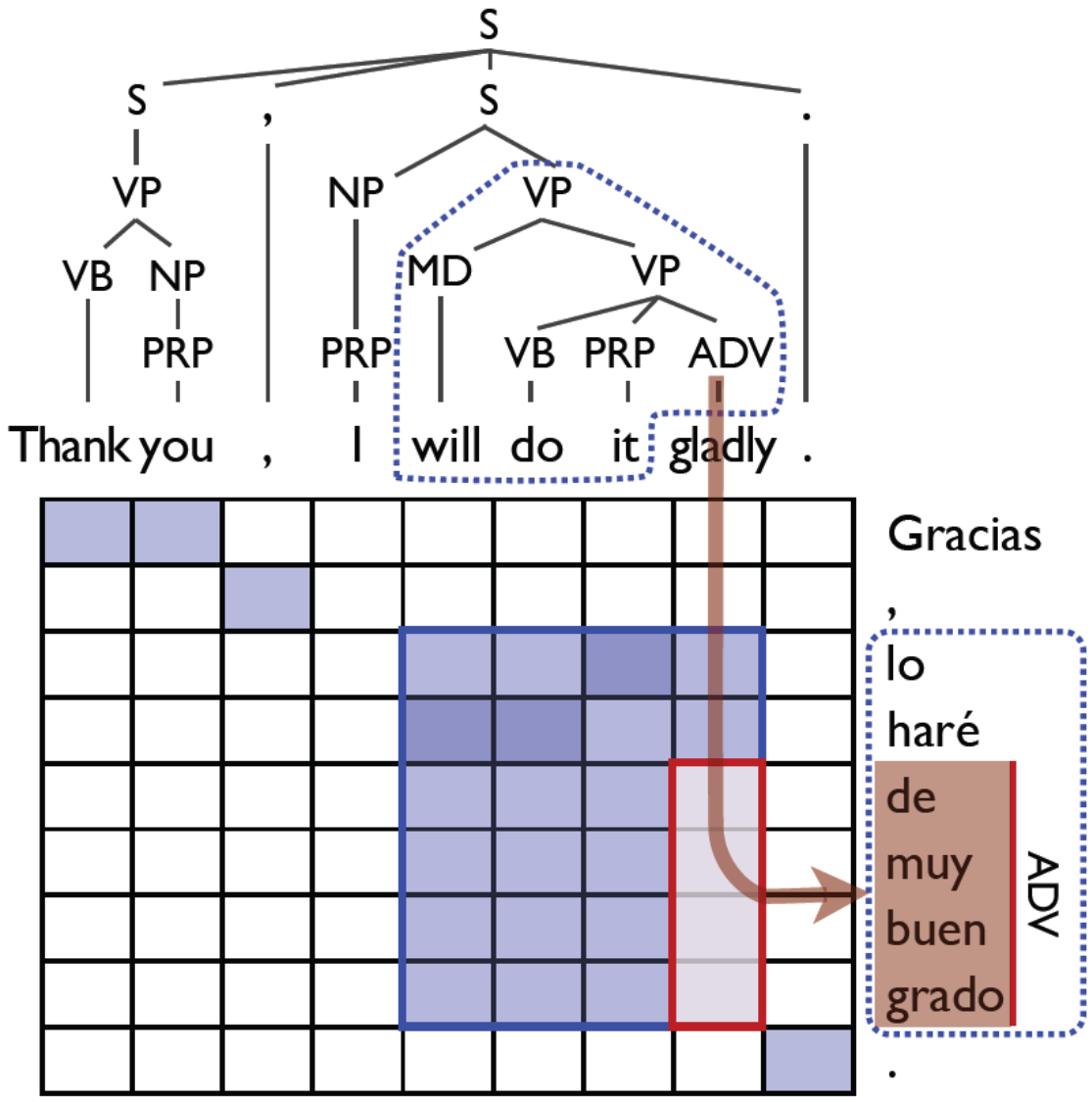

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VP →
⟨lo haré de ... grado ;
will do it gladly⟩

VP →
⟨lo haré ADV ;
will do it ADV⟩

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Berkeley

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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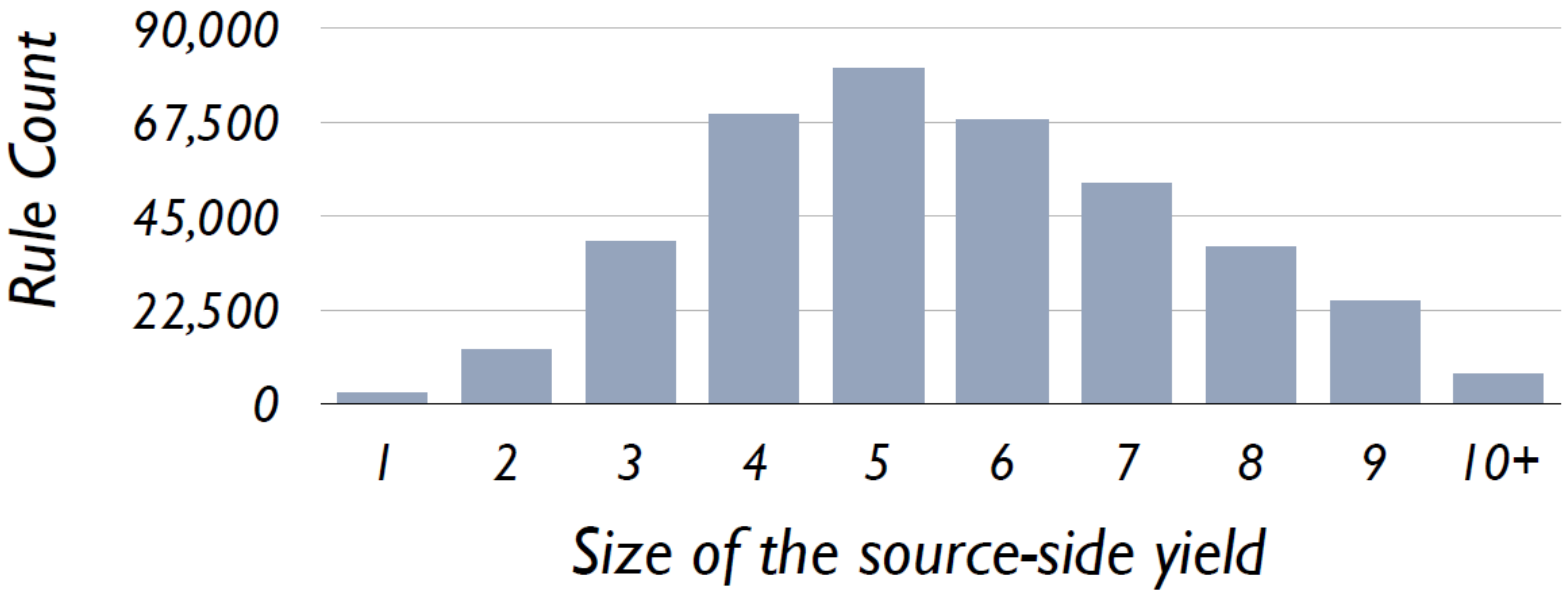
Rules matching an example 40-word sentence



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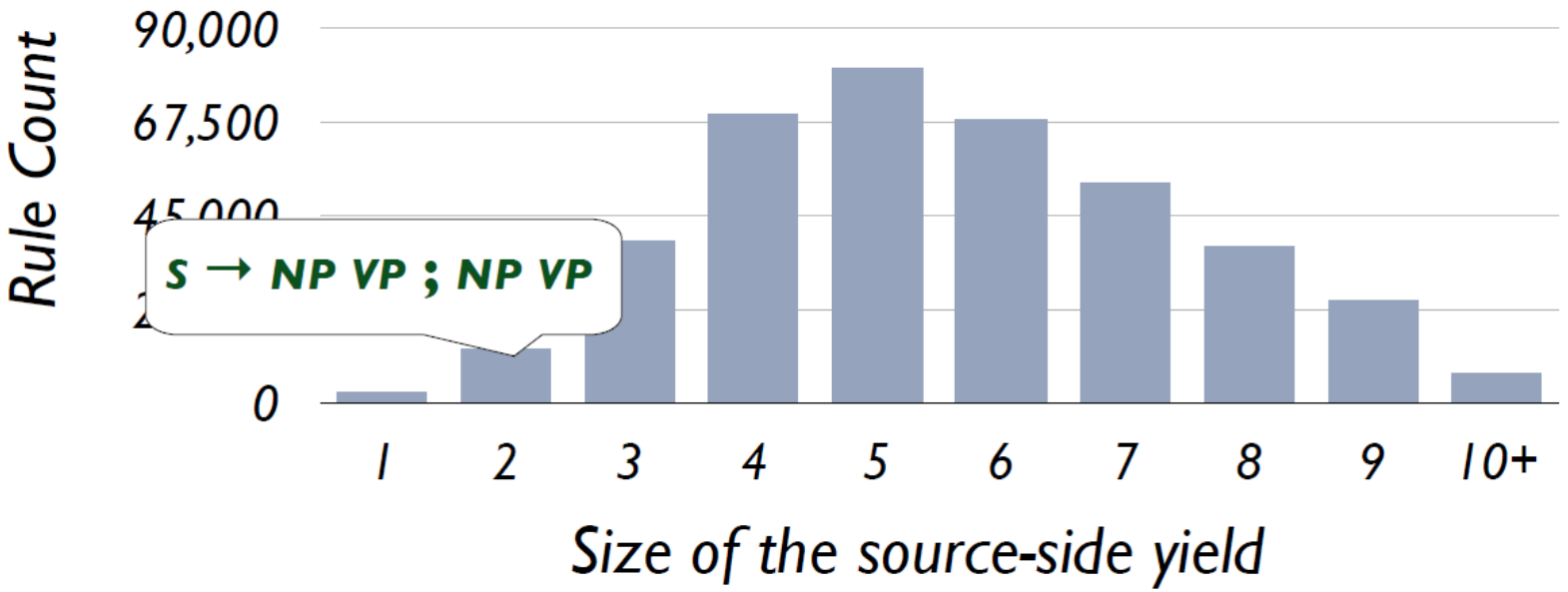

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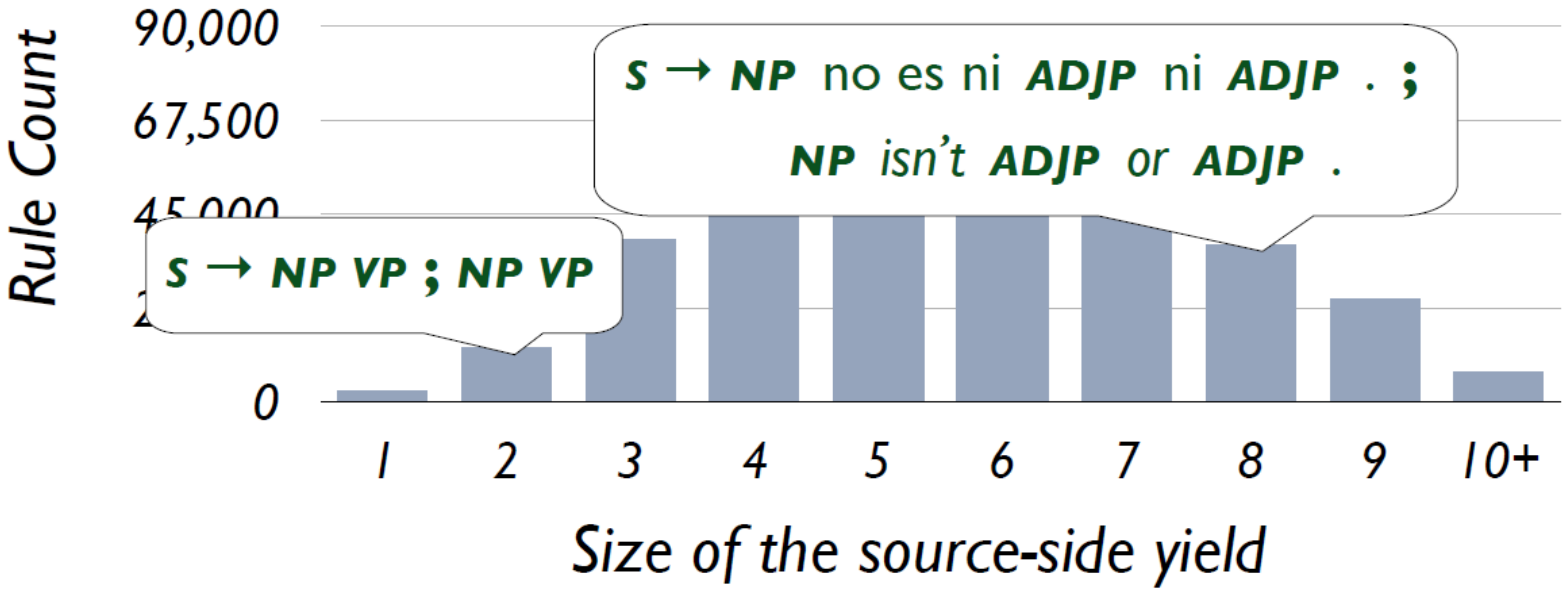
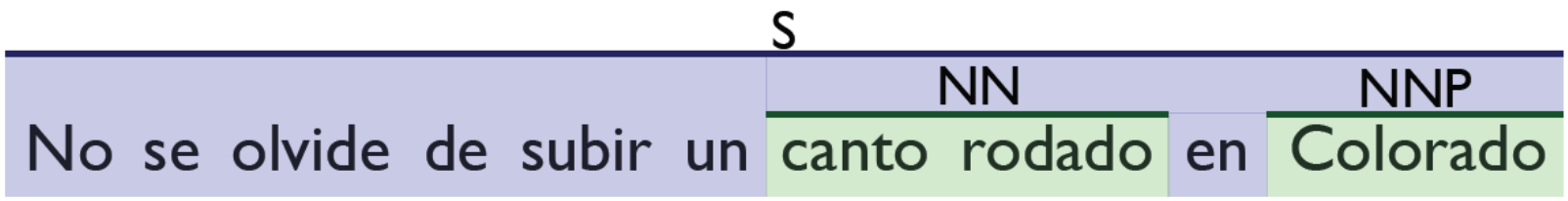


Syntactic Decoding

Tree Transducer Grammars



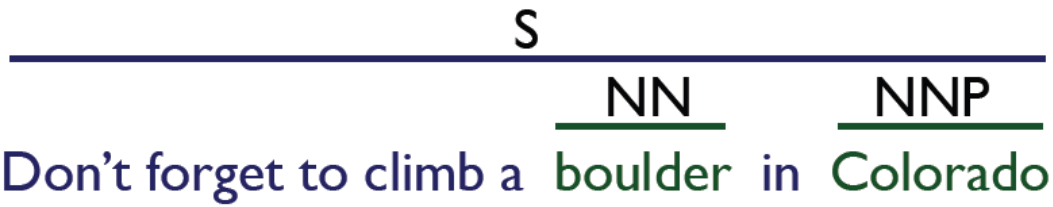
Synchronous Grammar

NNP → Colorado ; *Colorado*

NN → canto rodado ; *boulder*

S → No se olvide de subir un ***NN*** en ***NNP*** ; *Don't forget to climb a **NN** in **NNP***

Output



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Berkeley

CKY-style Bottom-up Parsing

For each
span length:

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N L P
Berkeley

CKY-style Bottom-up Parsing

For each span length:

For each span [i,j]:

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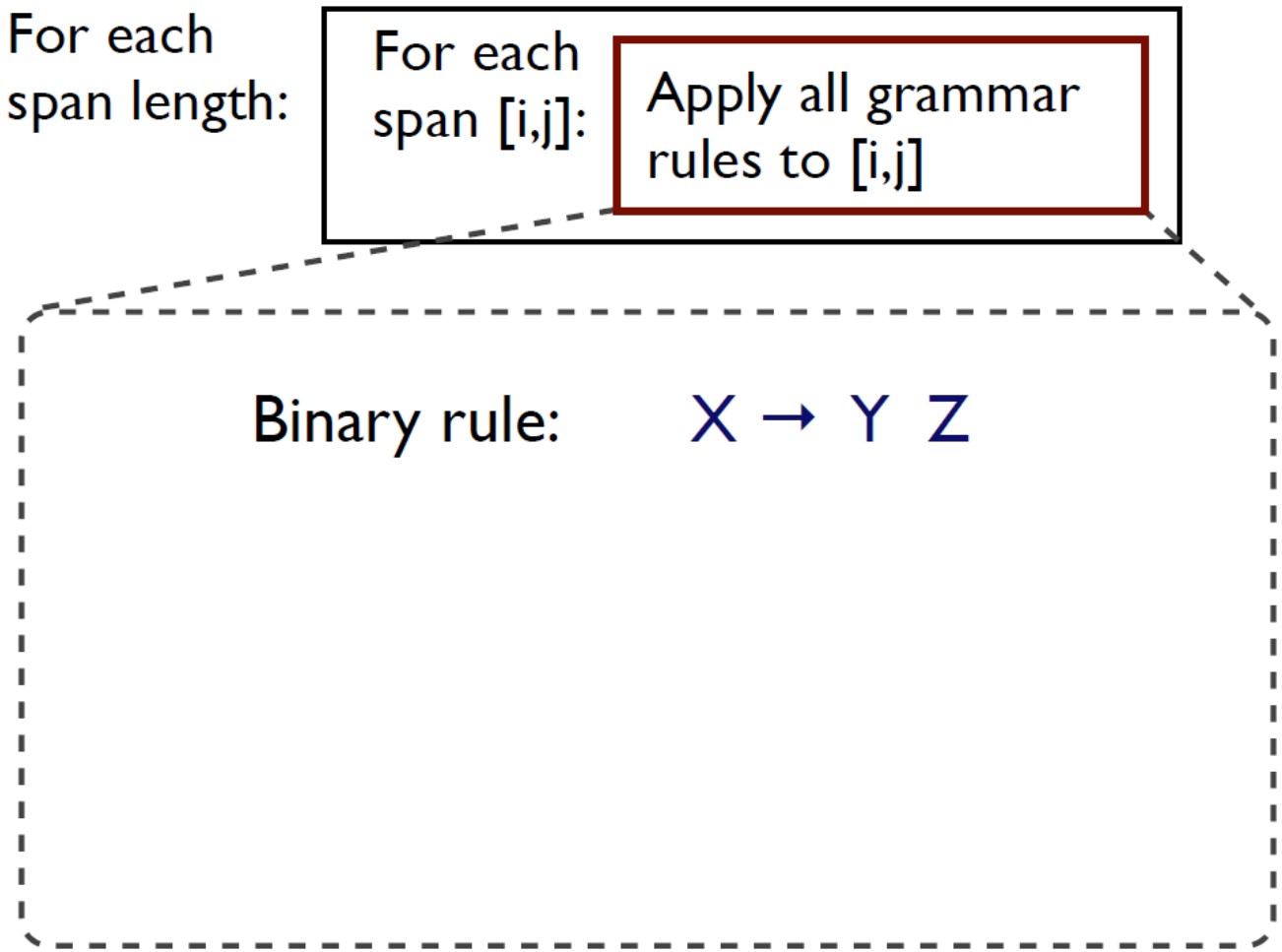

CKY-style Bottom-up Parsing

For each span length:

For each span [i,j]:

Apply all grammar rules to [i,j]

Binary rule: $X \rightarrow Y\ Z$

Split points: $i < k < j$

Operations: $O(j - i)$

Time scales with: Grammar constant

CKY-style Bottom-up Parsing

For each span length:

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Apply all grammar rules to [i,j]

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

CKY-style Bottom-up Parsing

For each span length:

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Apply all grammar rules to [i,j]

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

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

CKY-style Bottom-up Parsing

For each span length:

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

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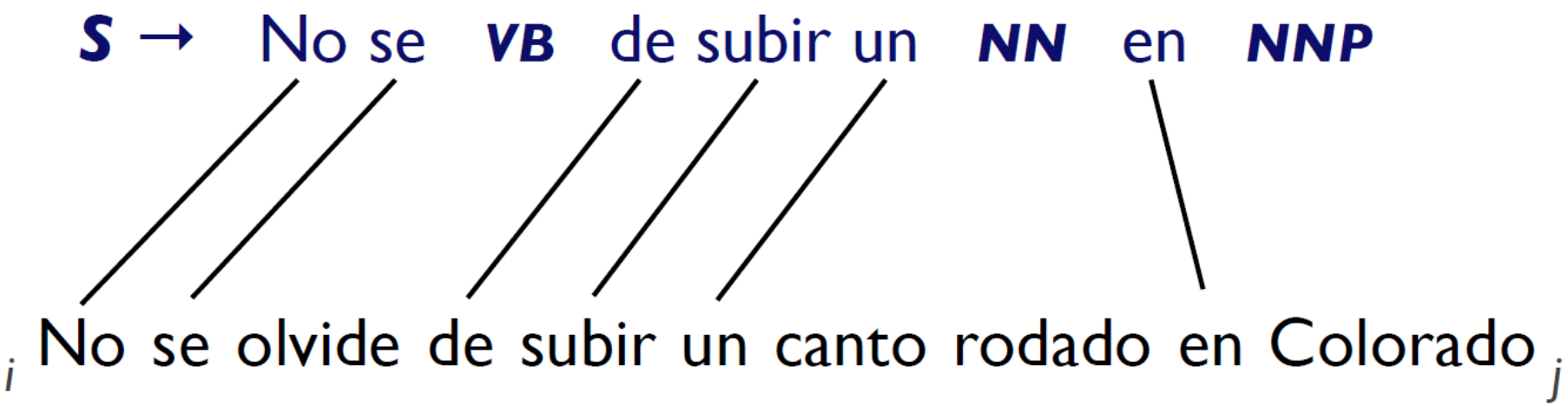

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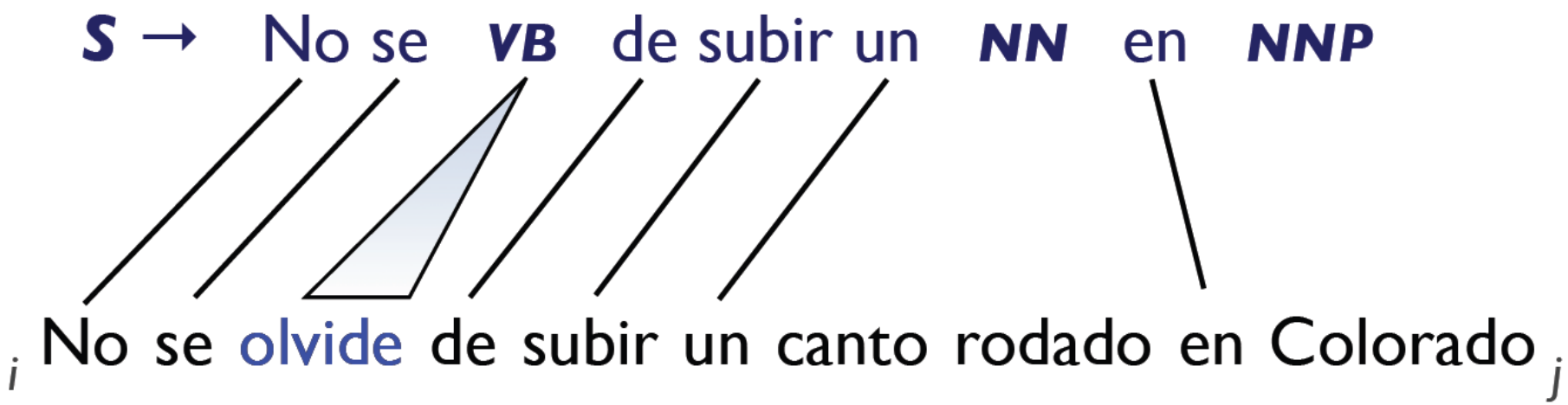

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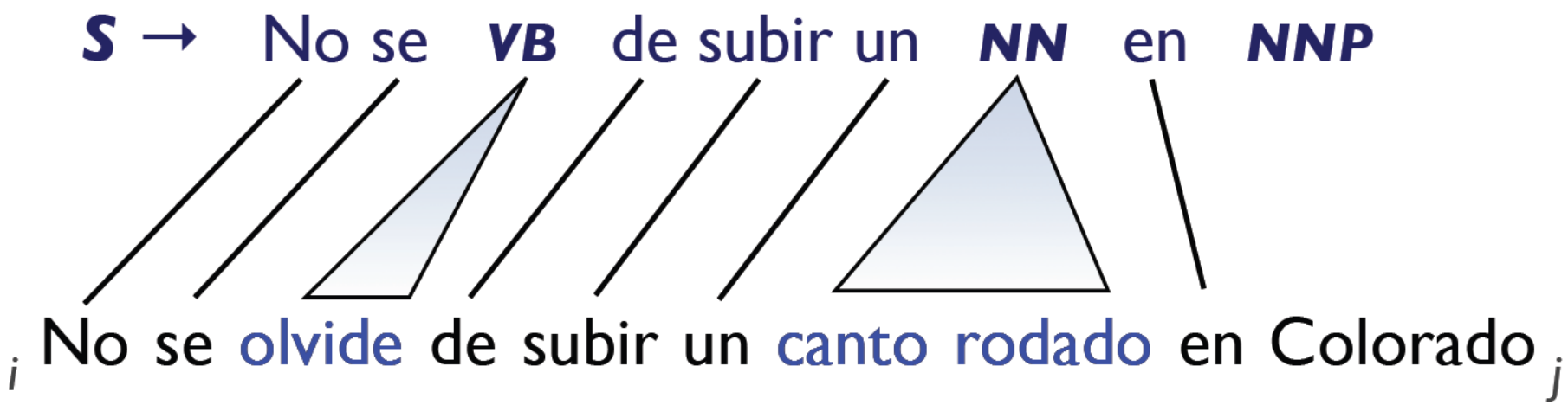

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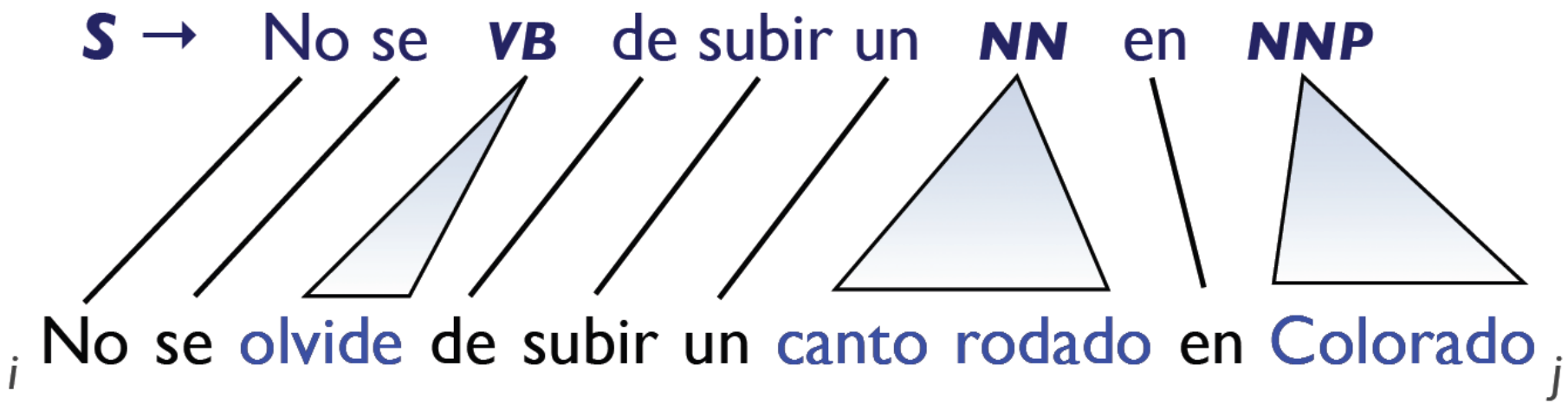
For each span [i,j]:

Apply all grammar rules to [i,j]

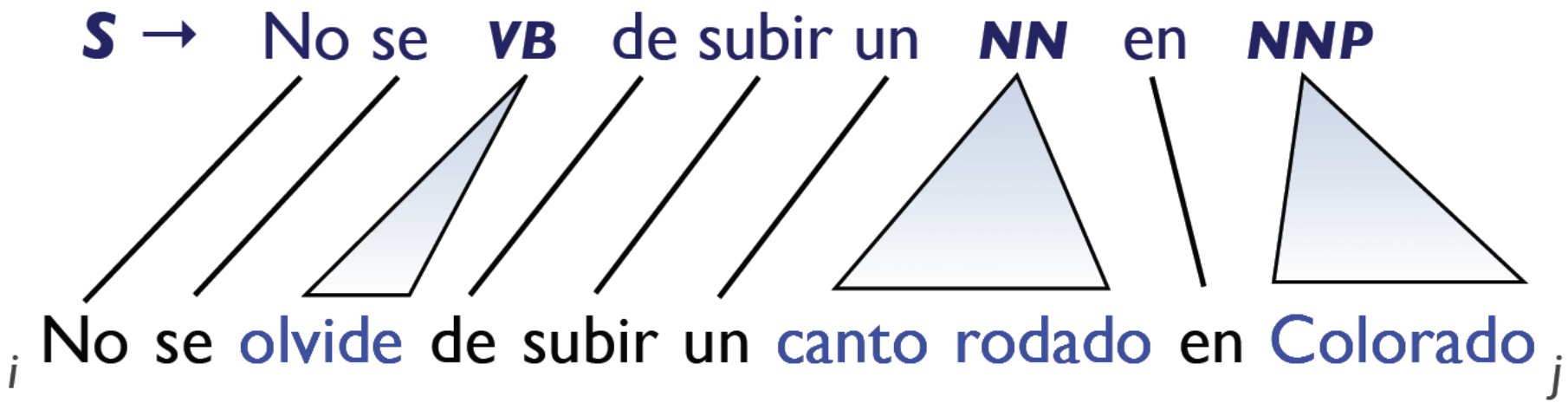


CKY-style Bottom-up Parsing

For each span length:

For each span [i,j]:

Apply all grammar rules to [i,j]



Many untransformed lexical rules can be applied in linear time

CKY-style Bottom-up Parsing

For each span length:

For each span [i,j]:

Apply all grammar rules to [i,j]

S → No se ***VP*** ***NP*** ***PP***

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

CKY-style Bottom-up Parsing

For each span length:

For each span [i,j]:

Apply all grammar rules to [i,j]

S → No se ***VP*** ***NP*** ***PP***

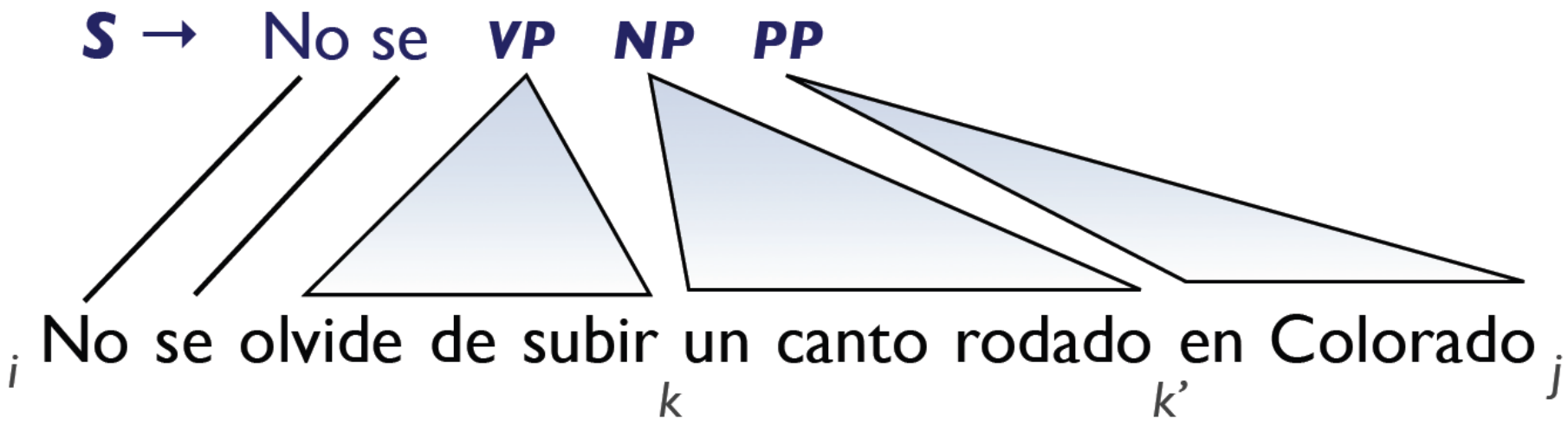
$_i$ No se olvide de subir un canto rodado en Colorado $_j$

CKY-style Bottom-up Parsing

For each span length:

For each span [i,j]:

Apply all grammar rules to [i,j]

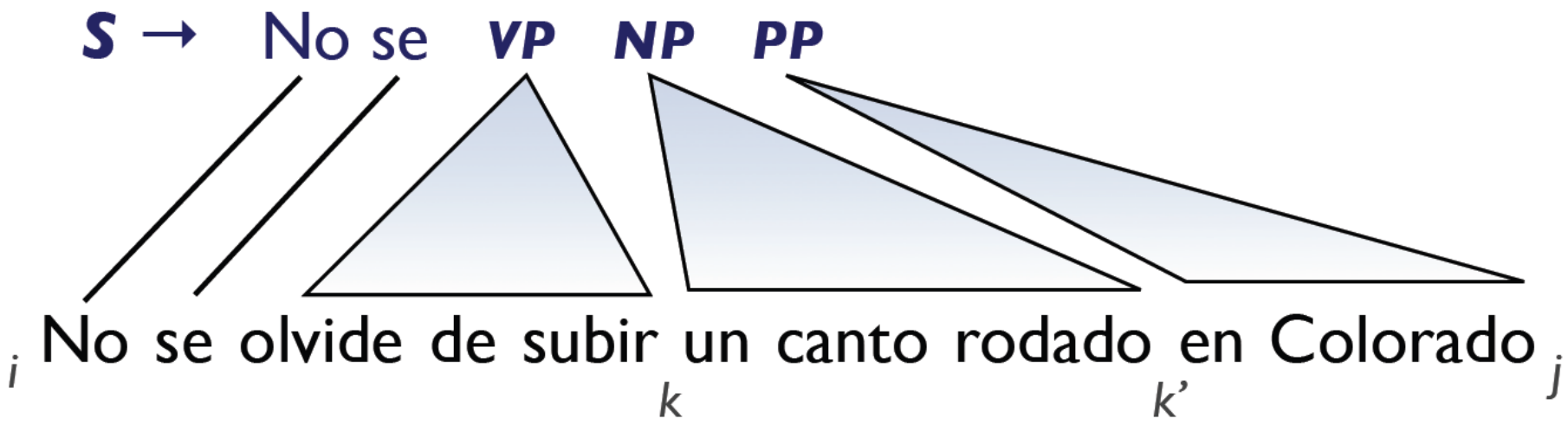


CKY-style Bottom-up Parsing

For each span length:

For each span [i,j]:

Apply all grammar rules to [i,j]



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.

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

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

VB~VB → **VB** **VB**

NN~PP → **NN** **PP**

Parsing stages:

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

Exploiting GPUs

Lots to Parse

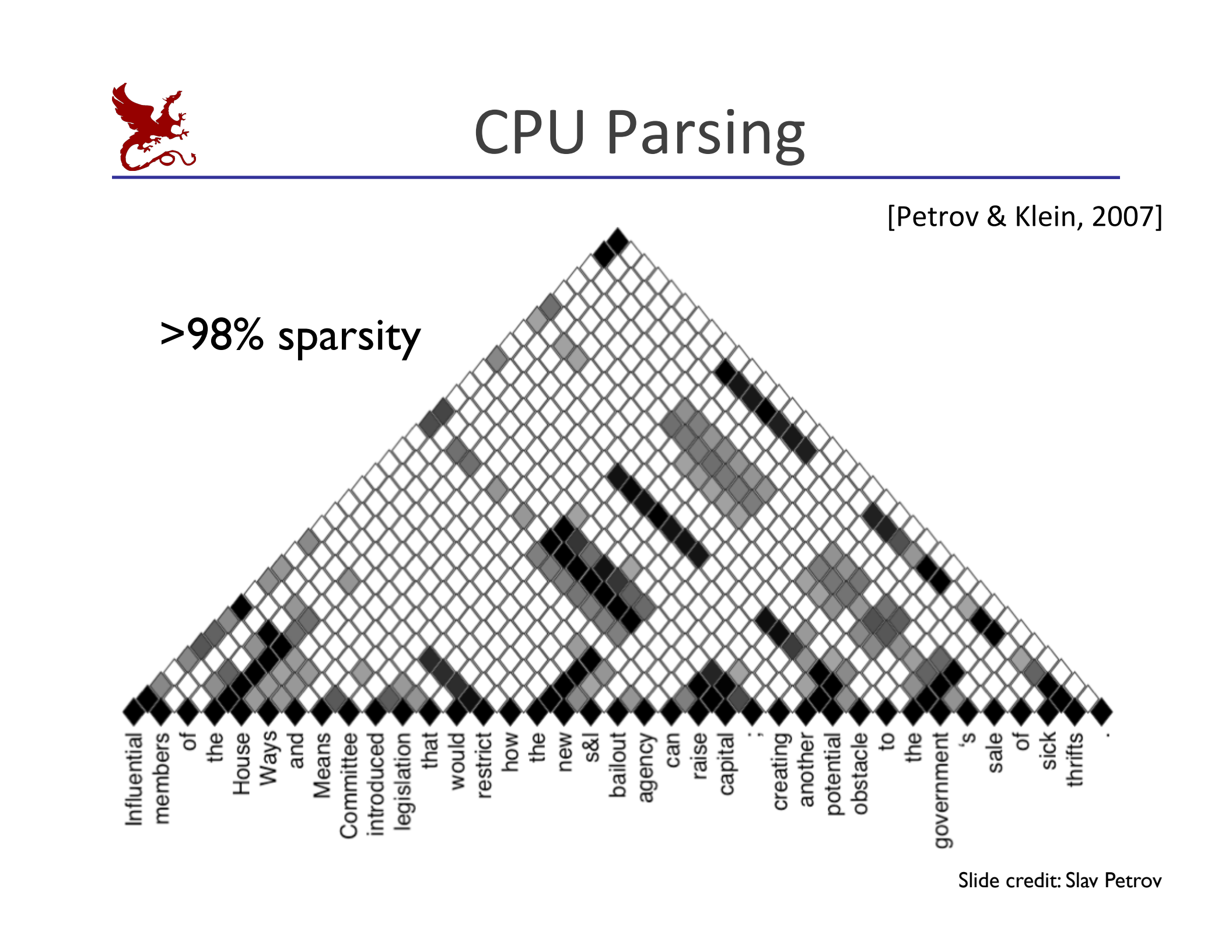
≈2.6 billion words

Lots to Parse

≈6 months (CPU)

Lots to Parse

≈3.6 days (GPU)



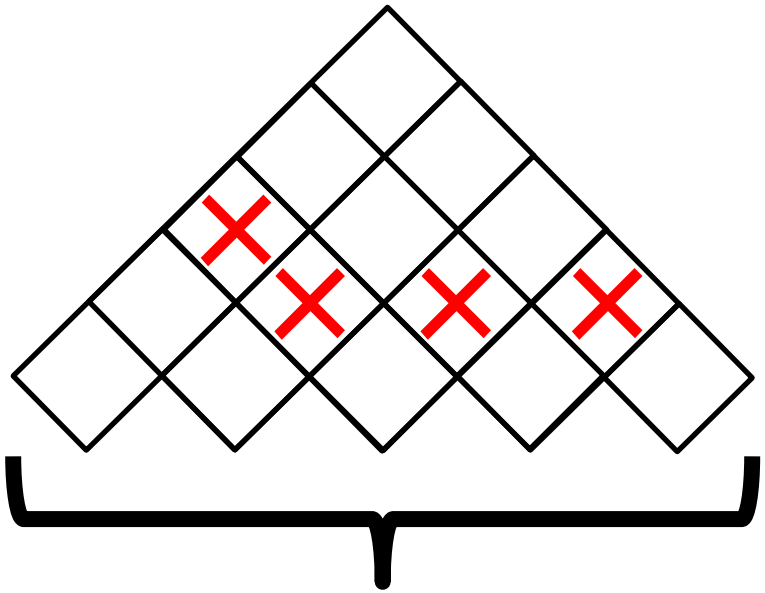
CPU Parsing

[Petrov & Klein, 2007]

>98% sparsity

Slide credit: Slav Petrov

CPU Parsing



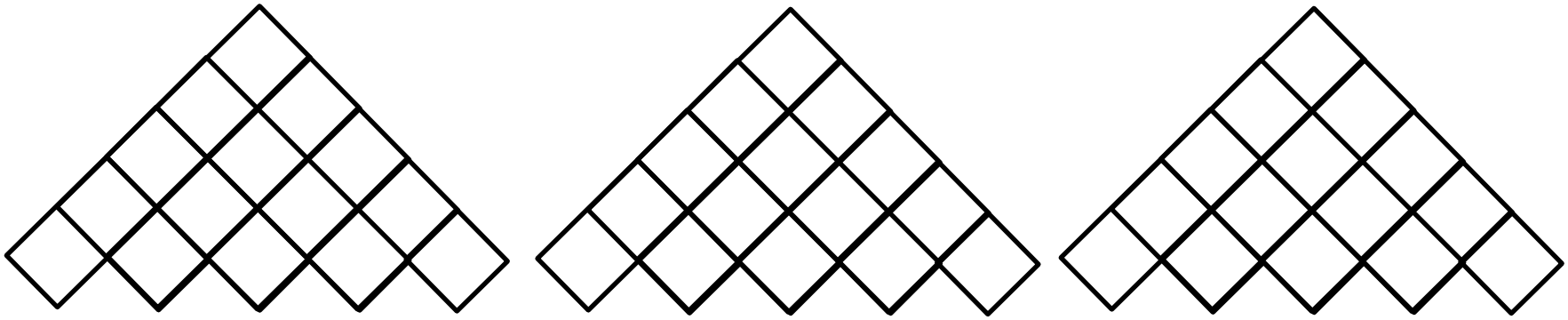
Skip Spans

Skip Rules

CPU Parsing

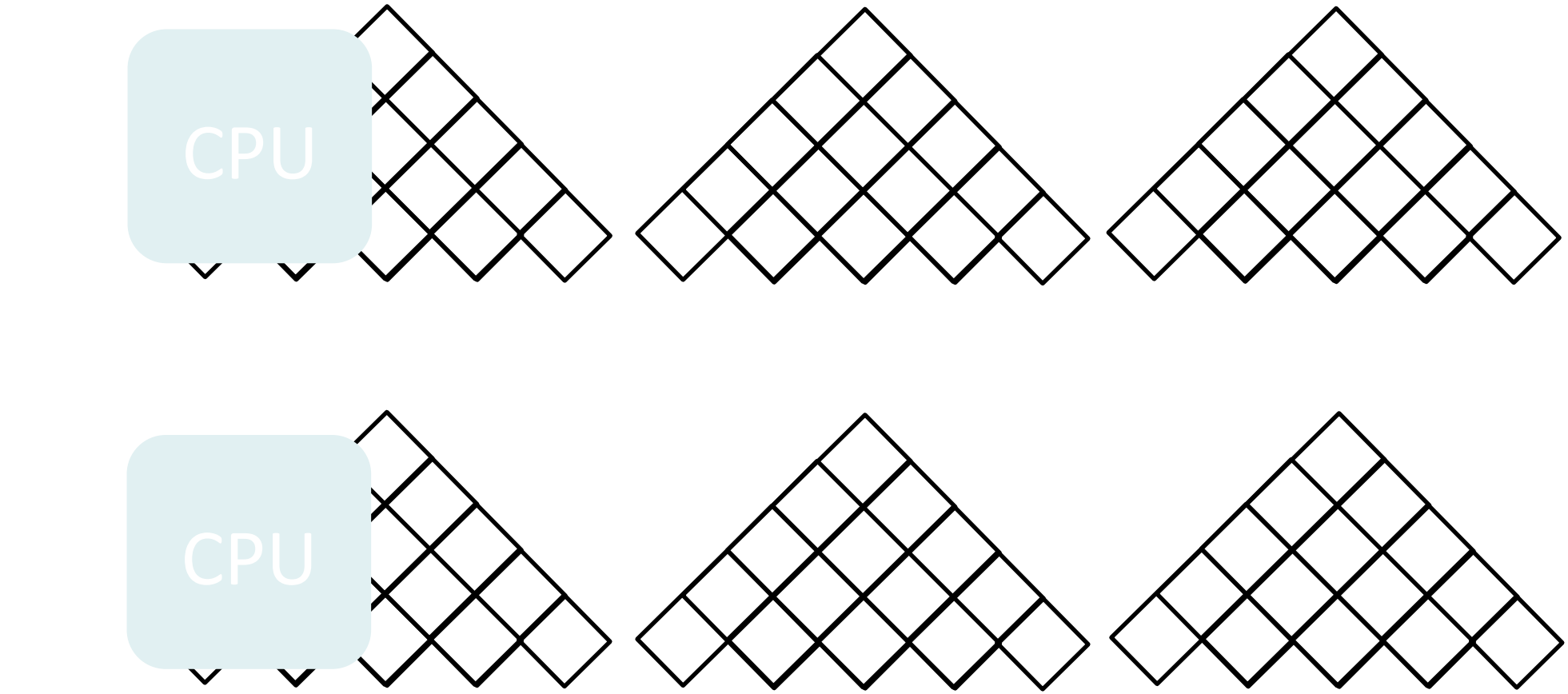
CPU

CPU Parsing



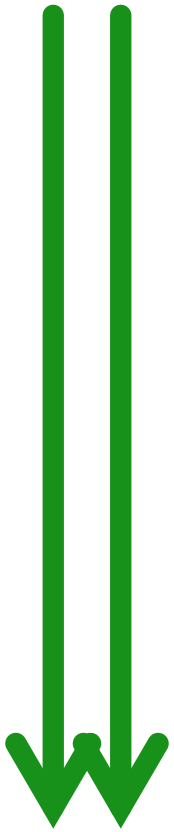
CPU

CPU Parsing

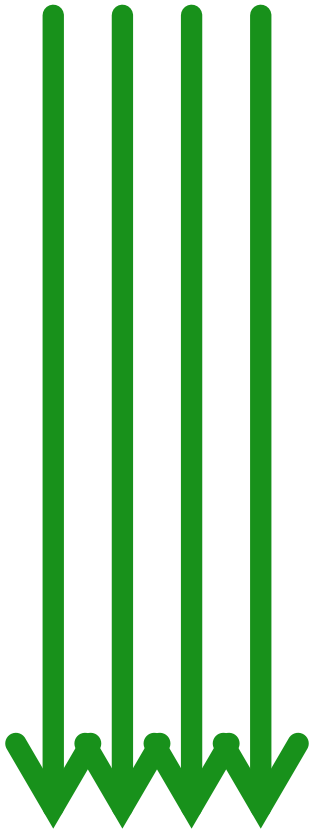


The Future of Hardware

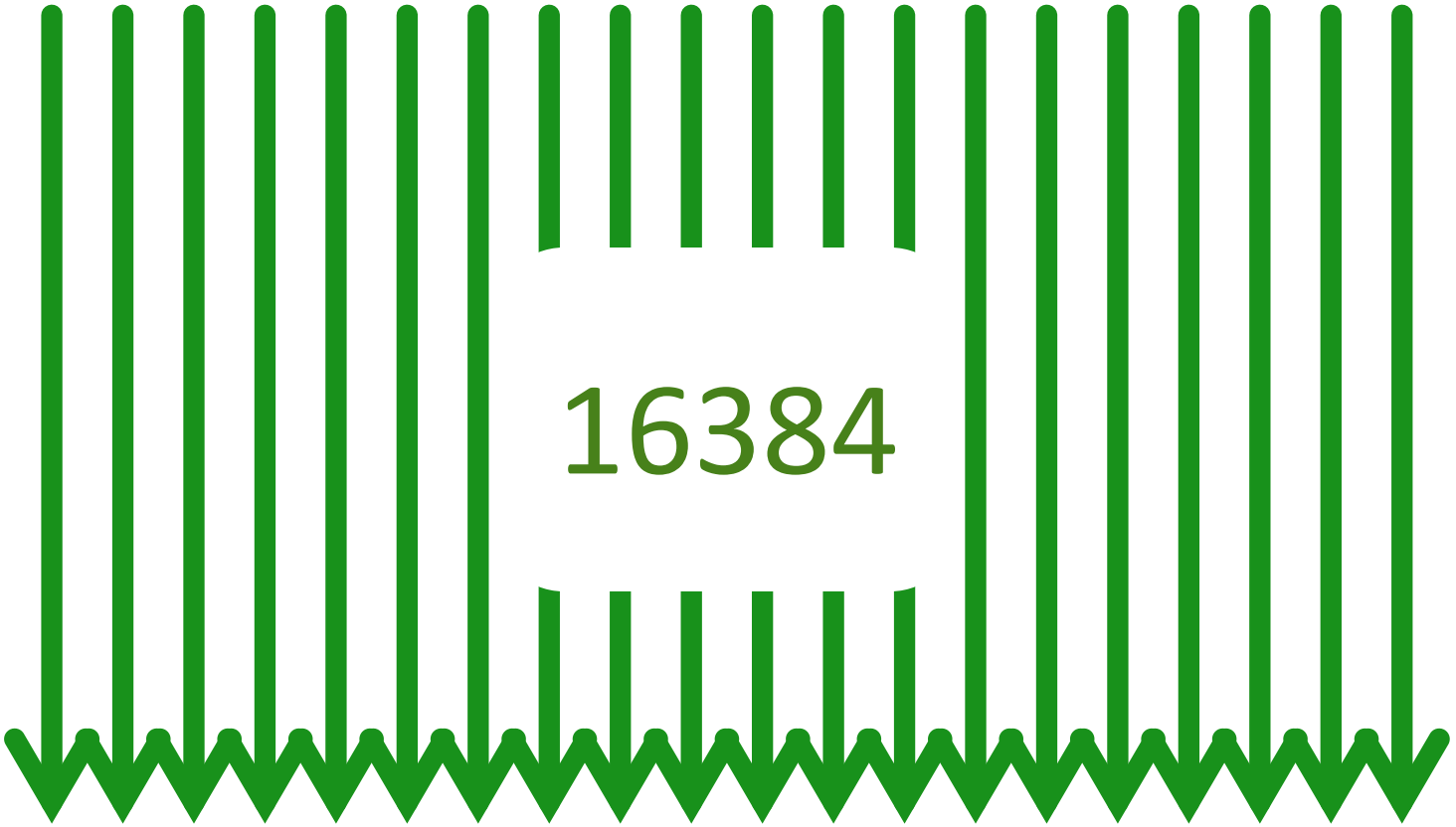
The Future of Hardware



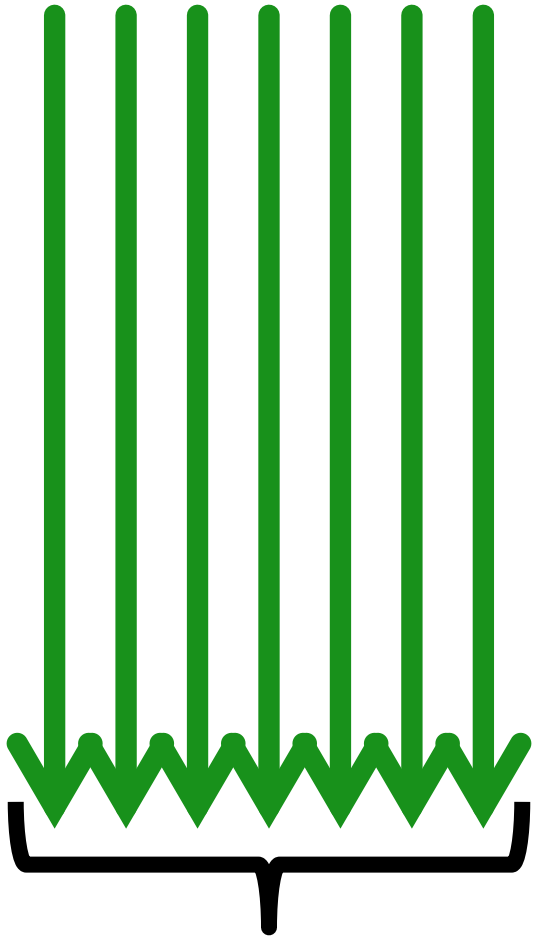
The Future of Hardware



The Future of Hardware



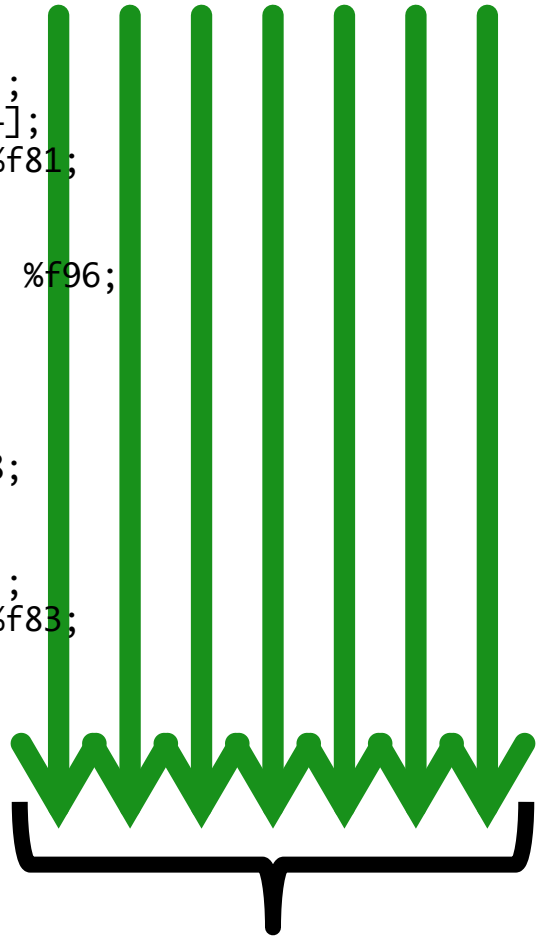
The Future of Hardware



32 Threads

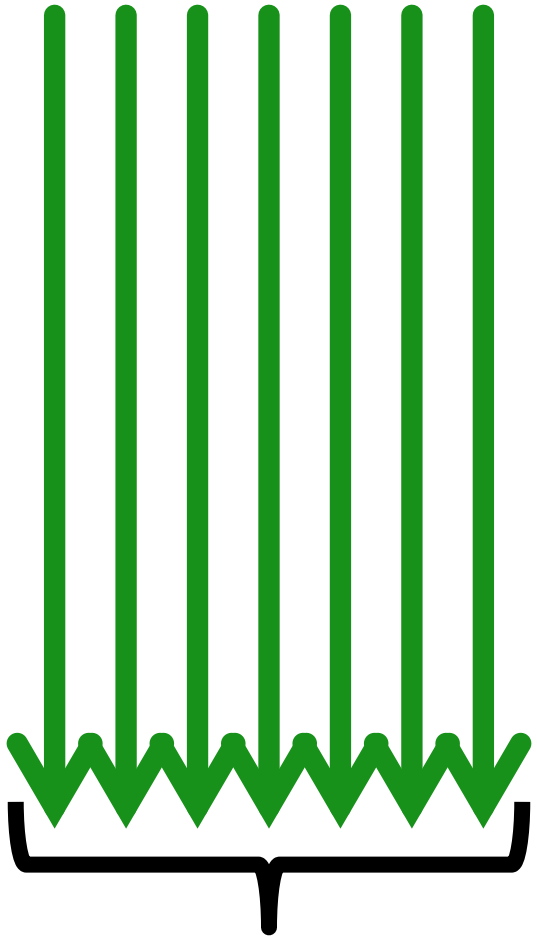
The Future of Hardware

```
add.s32   %r1, %r631, %r0;
ld.global.f32   %f81, [%r1];
ld.global.f32   %f82, [%r34];
mul.ftz.f32   %f94, %f82, %f81;
mov.f32   %f95, 0f3E002E23;
mov.f32   %f96, 0f00000000;
mad.f32   %f93, %f94, %f95, %f96;
shl.b32   %r2, %r646, 8;
add.s32   %r3, %r658, %r2;
shl.b32   %r4, %r3, 2;
add.s32   %r5, %r631, %r4;
mul.lo.s32  %r6, %r646, 588;
shl.b32   %r7, %r6, 1;
add.s32   %r8, %r5, %r7;
ld.global.f32   %f83, [%r8];
mul.ftz.f32   %f98, %f82, %f83;
```



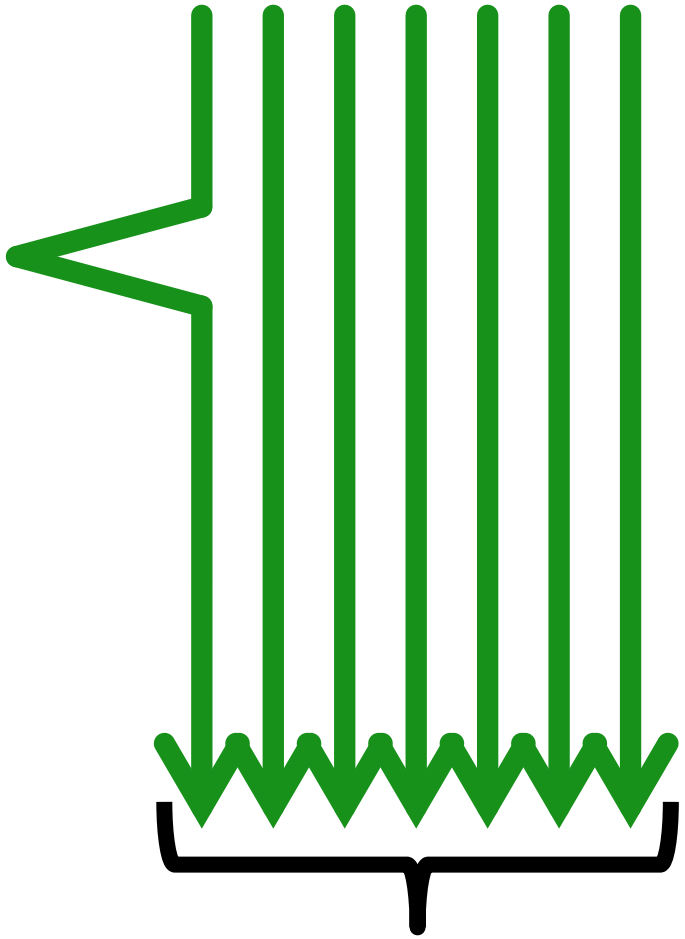
Warp

Warps



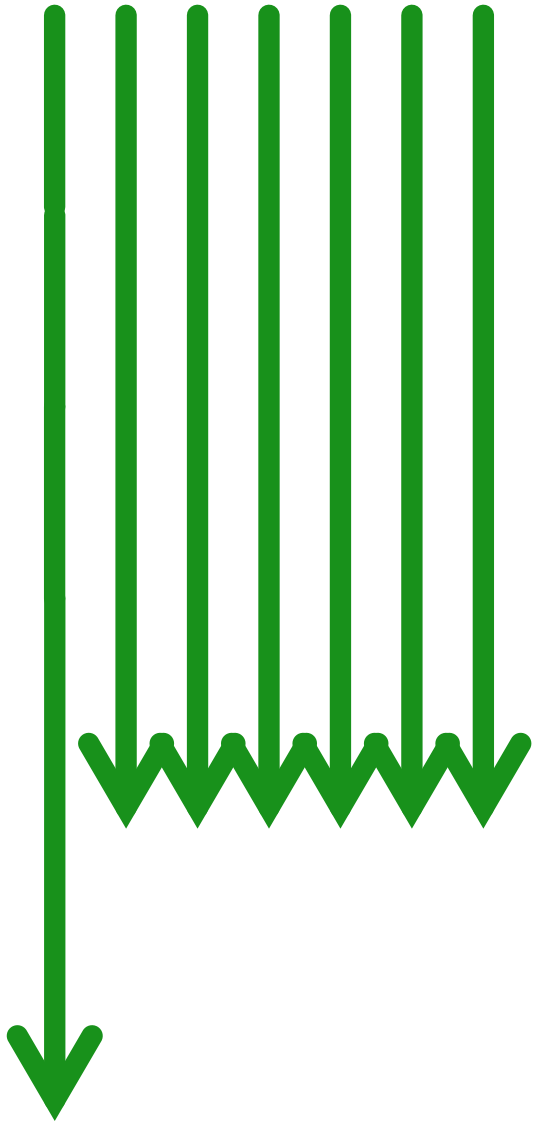
Warp

Warps

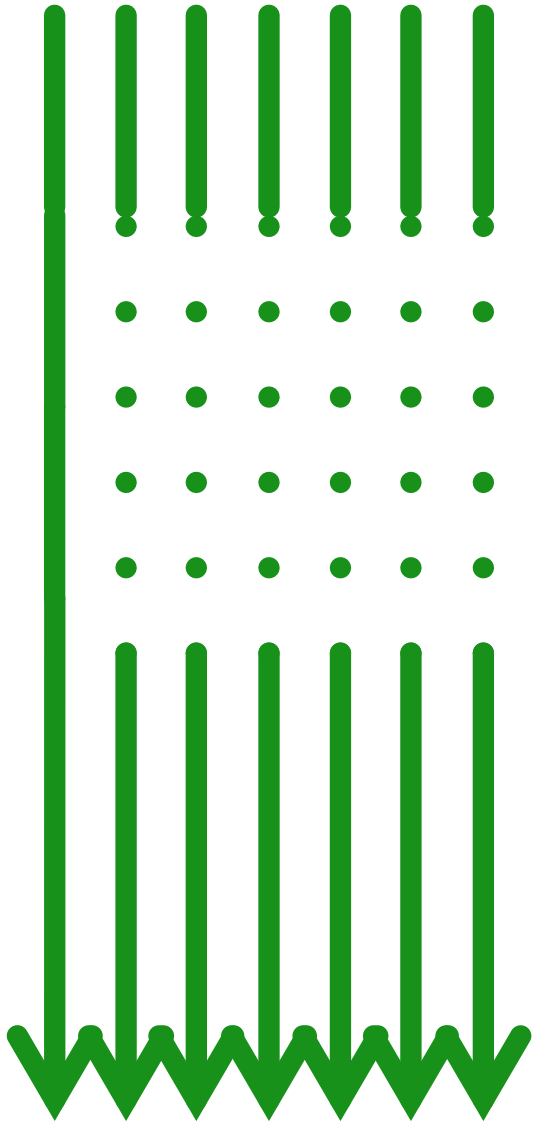


Warp Divergence

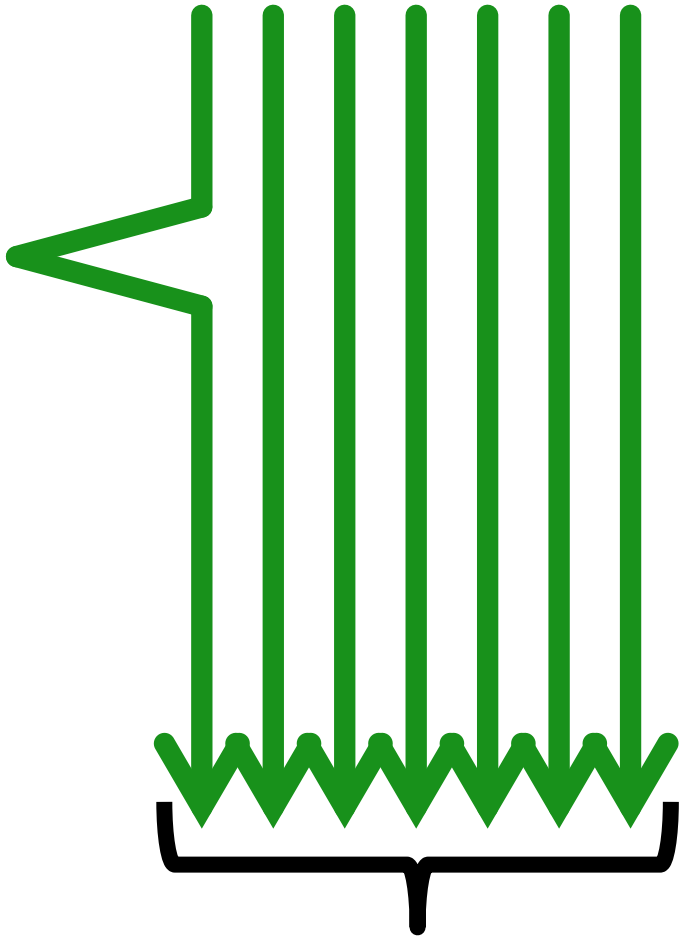
Warps



Warps

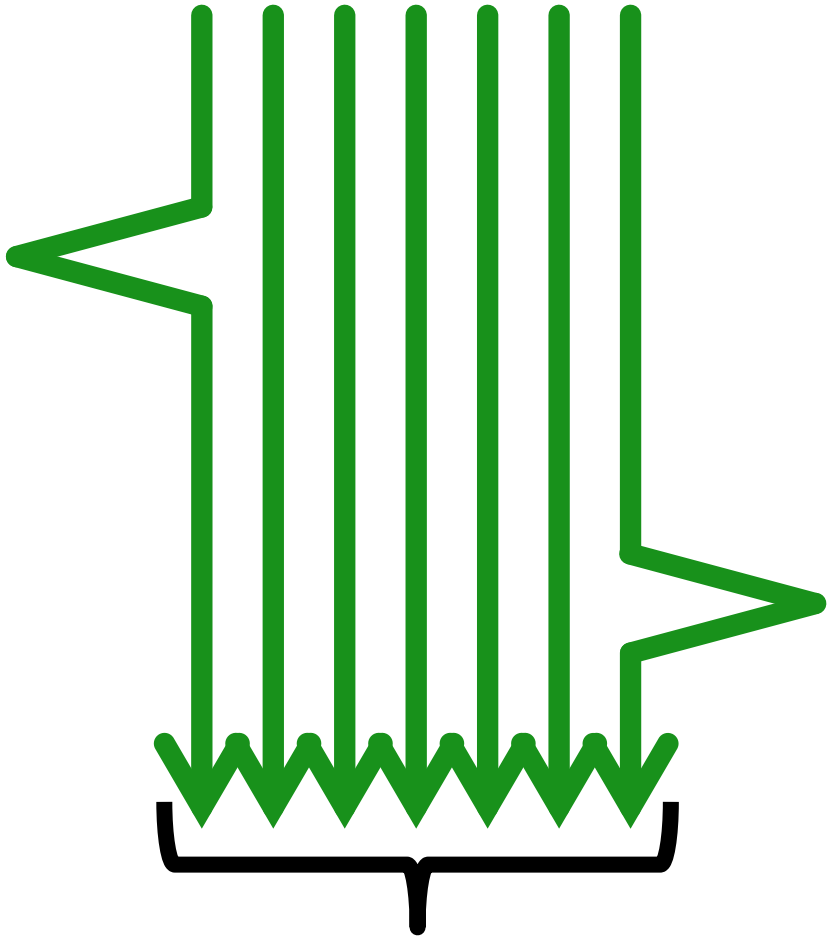


Warps



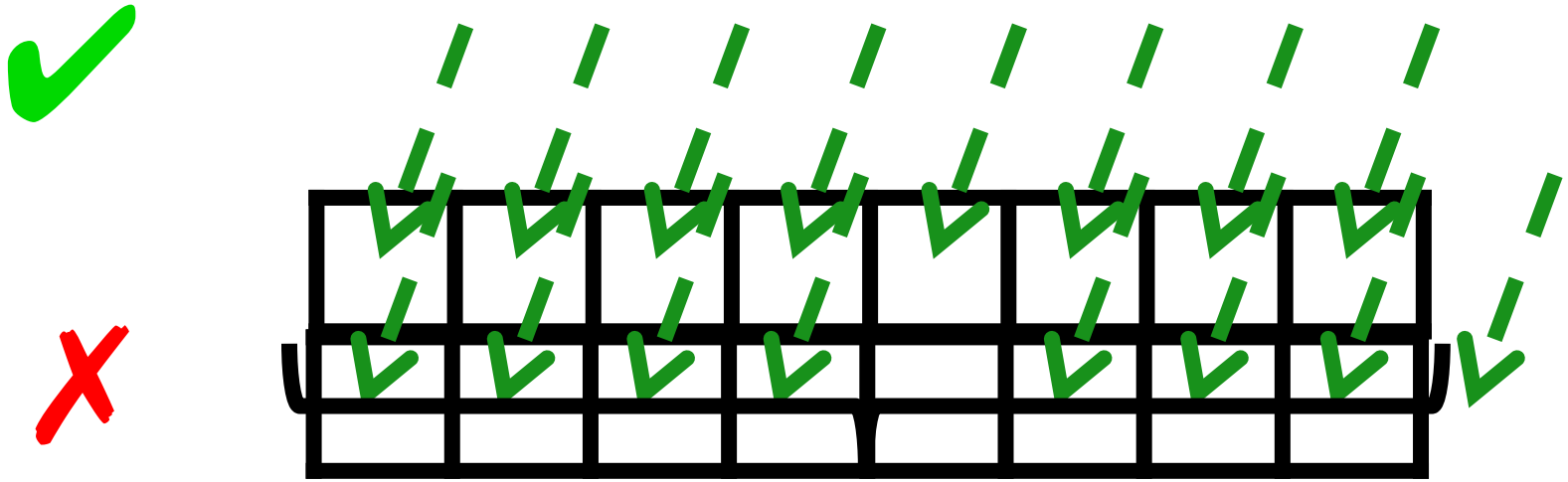
Warp Divergence

Warps



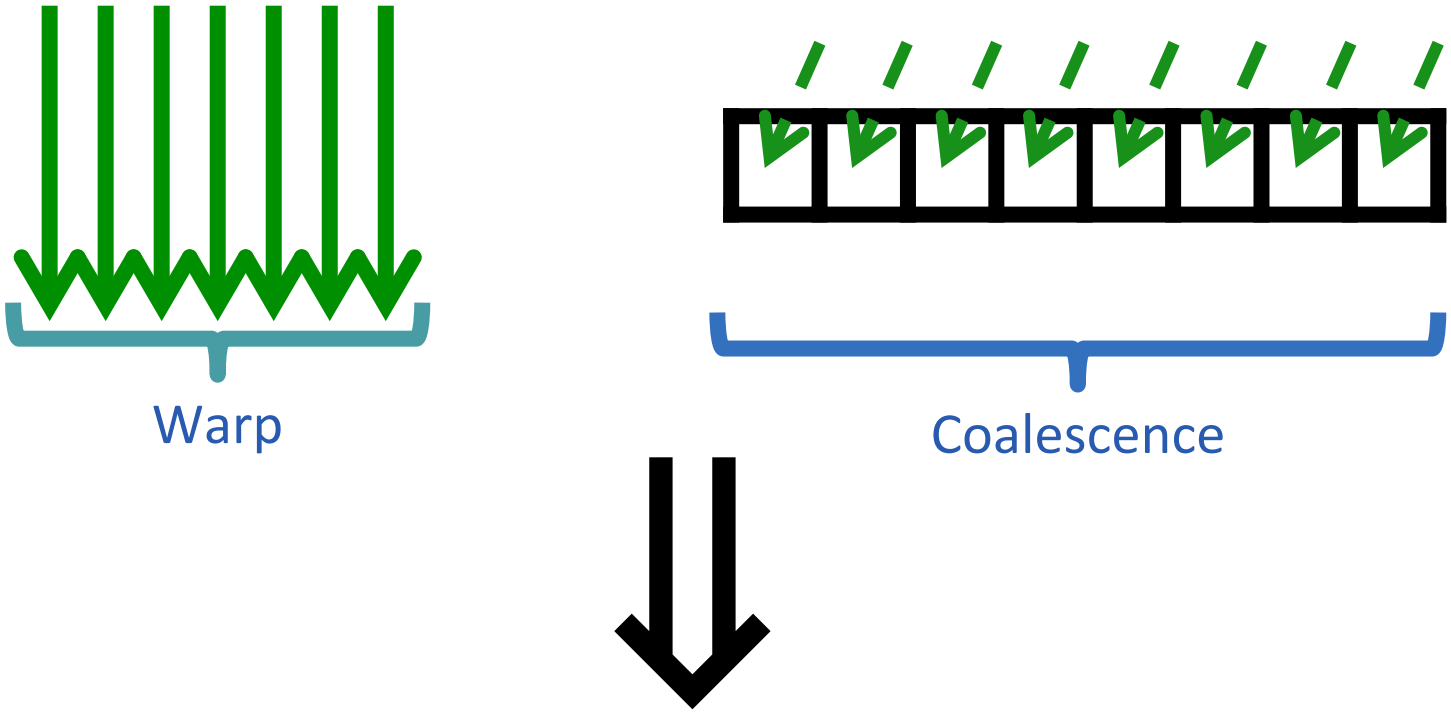
Warp Divergence

Warps



Coalescence

Designing GPU Algorithms



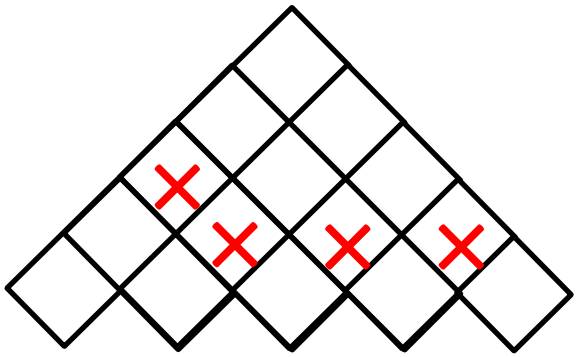
Dense, Uniform Computation

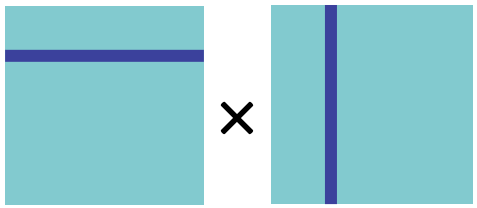
Designing GPU Algorithms

CPU

Irregular,
Sparse

Regular,
Dense



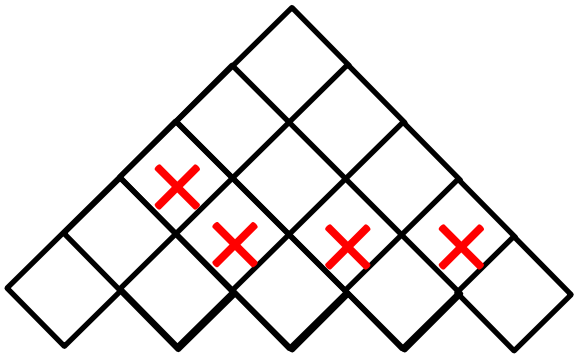


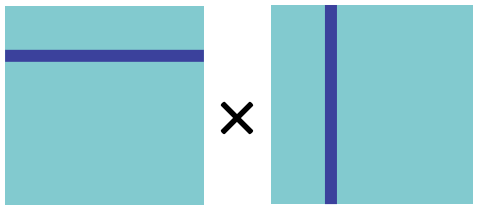
Designing GPU Algorithms

CPU

Irregular,
Sparse

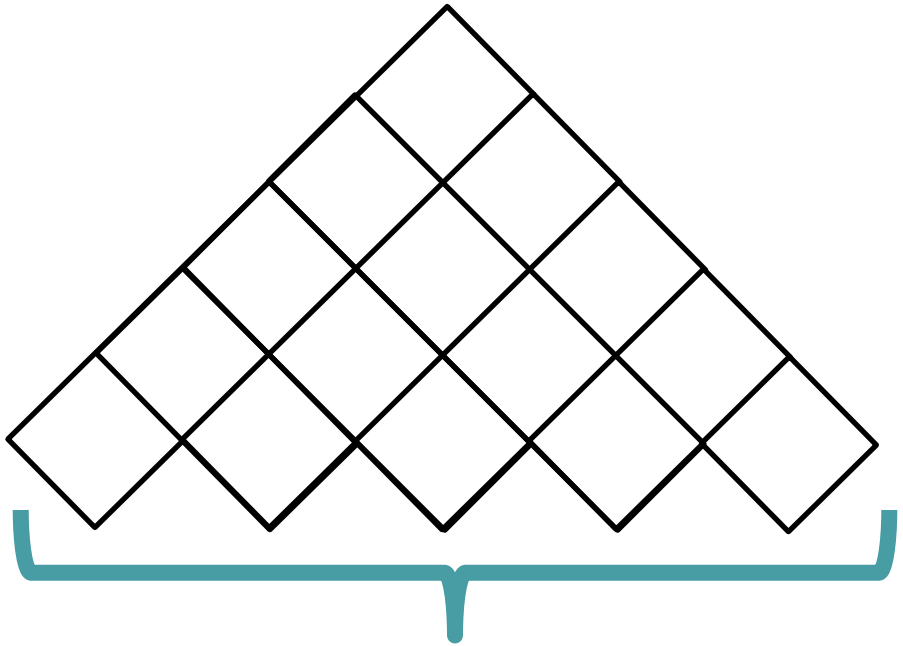
Regular,
Dense





[Canny, Hall, and Klein, 2013]

Designing GPU Algorithms



CKY Parsing

```
for each sentence:
  for each span (begin, end):
    for each split:
      for each rule (P -> L R):
        score[begin, end, P]
         += ruleScore[P -> L R]
           * score[begin, split, L]
           * score[split, end, R]
```

Item Queue

Grammar Application

CKY Parsing

```
for each sentence:
  for each span (begin, end):
    for each split:

      applyGrammar(begin, split, end)
```

Item Queue

Grammar Application

CKY Parsing

```
for each parse item in sentence:
    applyGrammar(item)
```

Item Queue

Grammar Application

CKY Parsing

```
for each parse item in sentence:
```

CPU

```
    applyGrammar(item)
```

GPU

GPU Parsing Pipeline

CPU

Queue

(i, k, j)

(0, 1, 3)

(0, 2, 3)

(1, 2, 4)

(1, 3, 4)

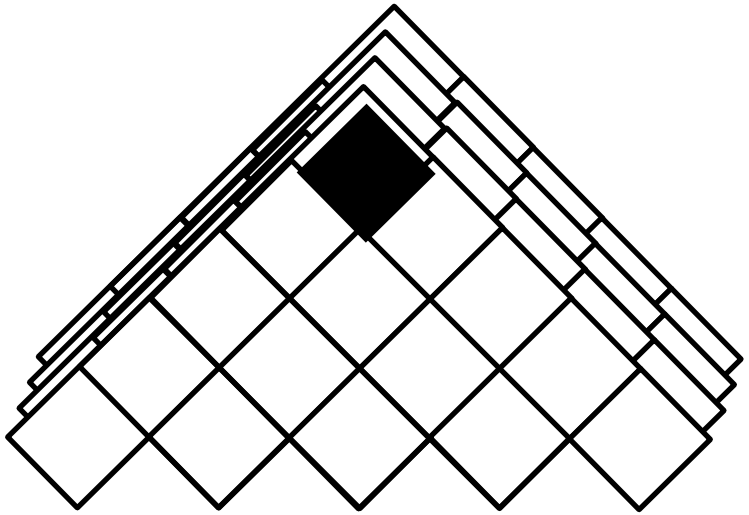
⋮

3

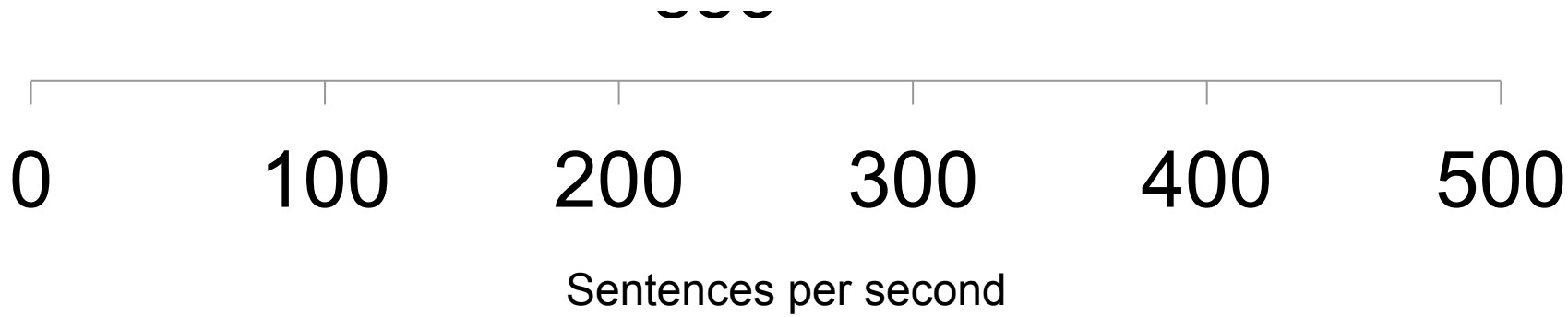
2

GPU

Grammar

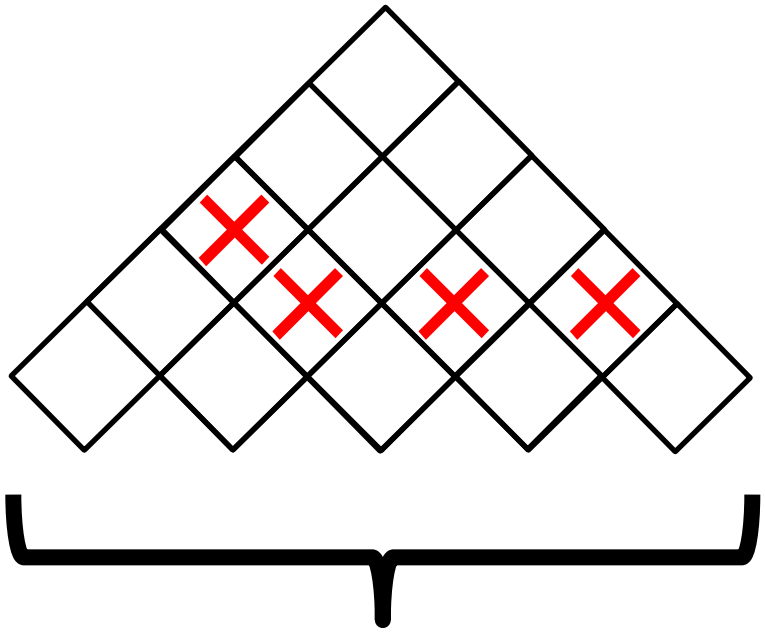


Parsing Speed

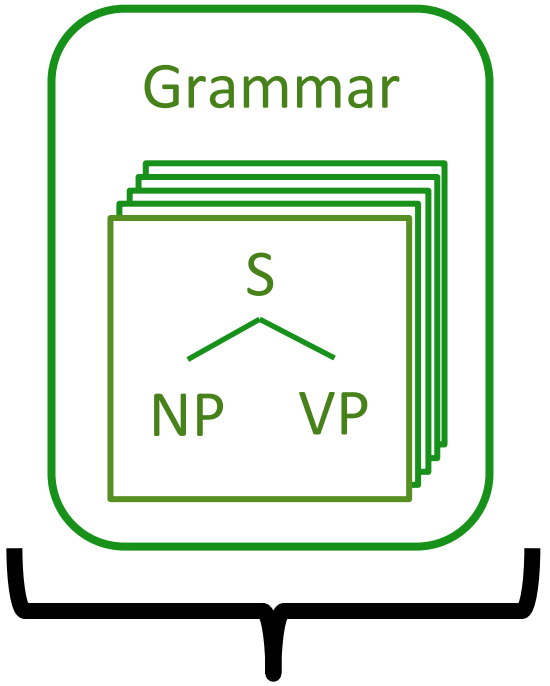


[Canny, Hall, and Klein, 2013]

Exploiting Sparsity

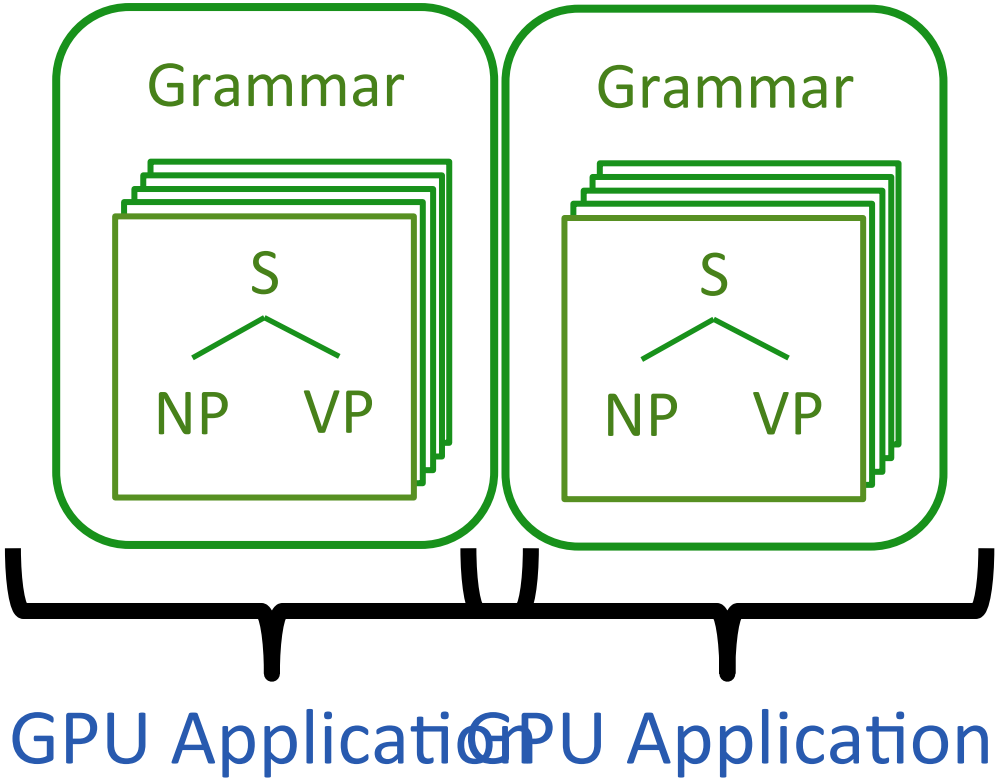


CPU Queuing

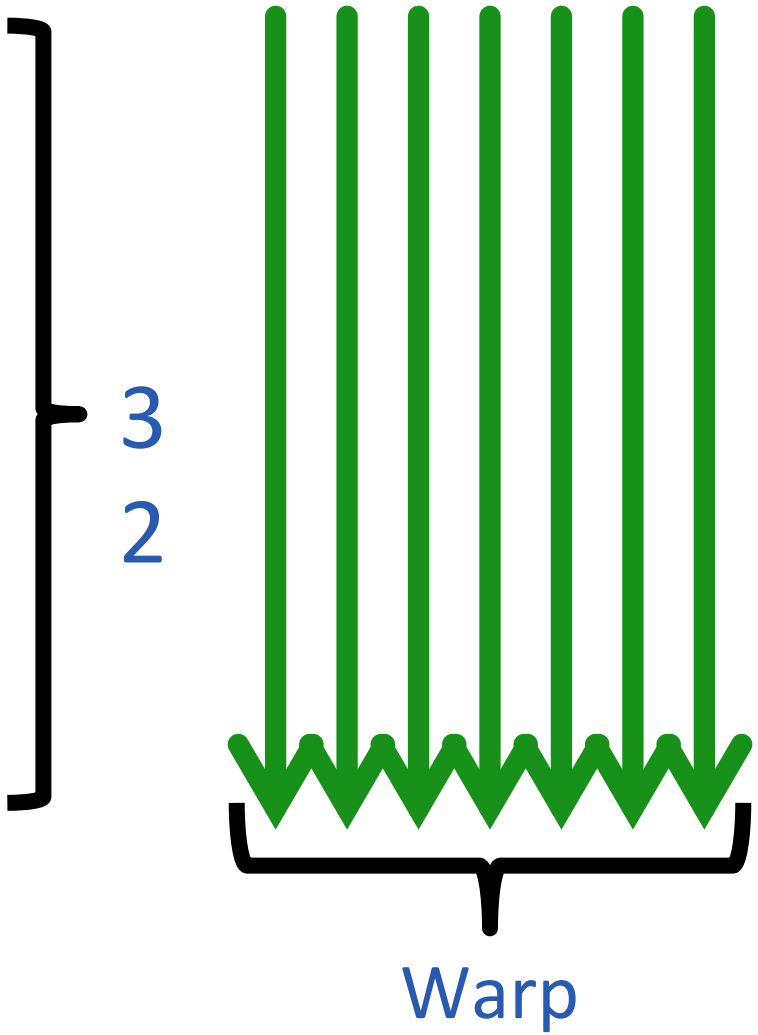


GPU Application

Exploiting Sparsity



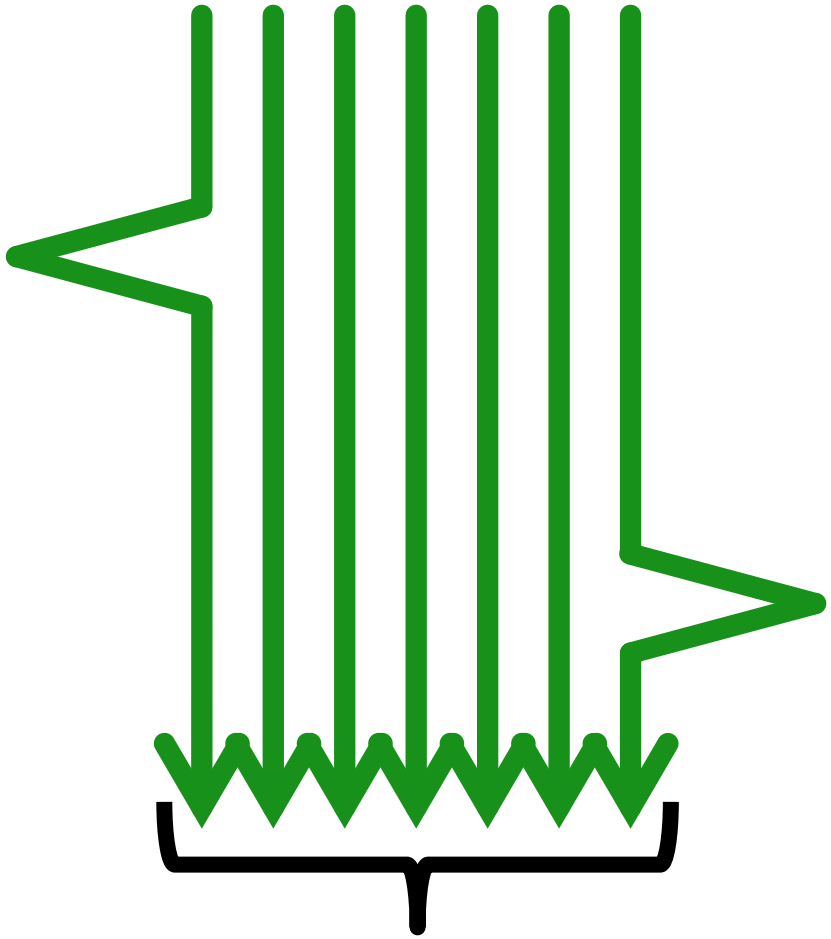
Exploiting Sparsity



Exploiting Sparsity

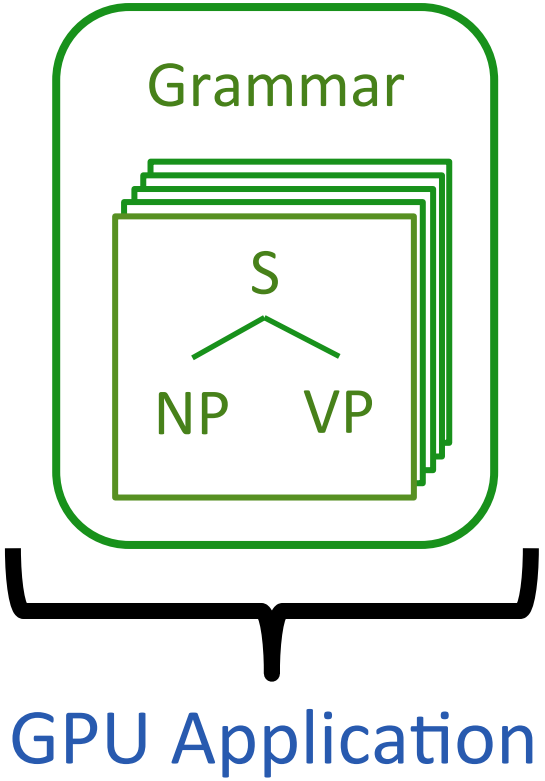
(0, 1, 3)	~~S~~	NP	~~VP~~	~~PP~~	…
(0, 2, 3)	~~S~~	~~NP~~	VP	~~PP~~	…
(1, 2, 4)	~~S~~	NP	~~VP~~	PP	…
(1, 3, 4)	~~S~~	NP	VP	~~PP~~	…
(2, 3, 5)	~~S~~	NP	VP	~~PP~~	…
(2, 4, 5)	~~S~~	NP	~~VP~~	PP	…
(3, 4, 6)	~~S~~	NP	~~VP~~	PP	…
⋮					

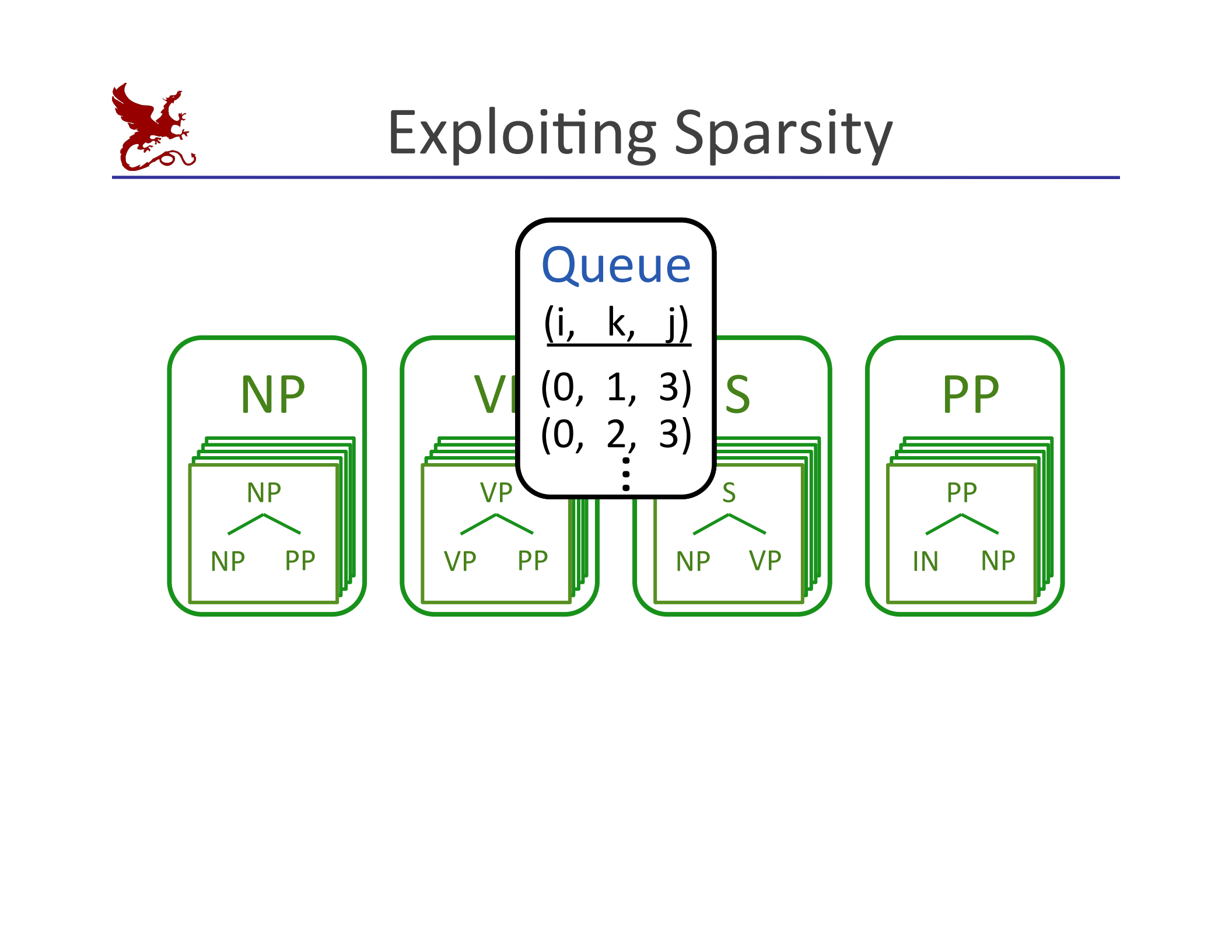
Exploiting Sparsity



Warp Divergence

Exploiting Sparsity





Exploiting Sparsity

Exploiting Sparsity

CPU

NP Queue

(i, k, j)

(0, 1, 3)

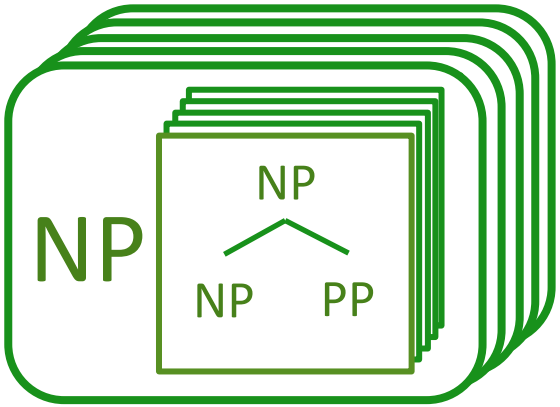
(0, 2, 3)

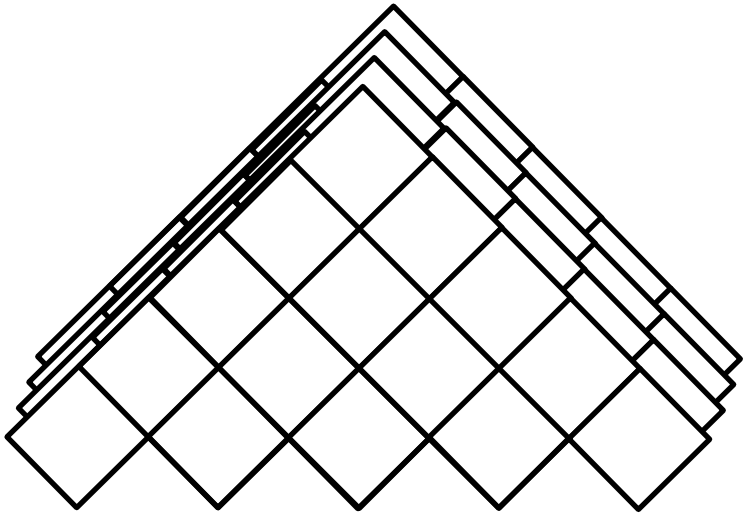
~~(1, 2, 4)~~

~~(1, 3, 4)~~

⋮

GPU





Exploiting Sparsity

CPU

VP Queue

(i, k, j)

~~(0, 1, 3)~~

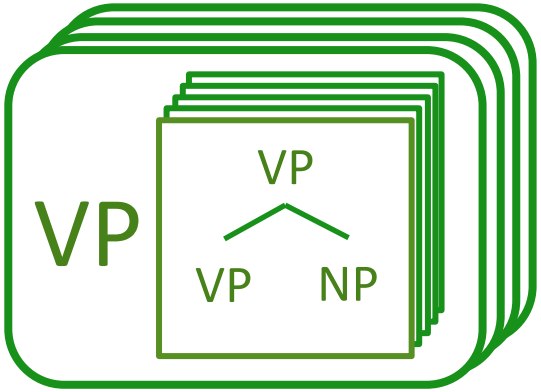
~~(0, 2, 3)~~

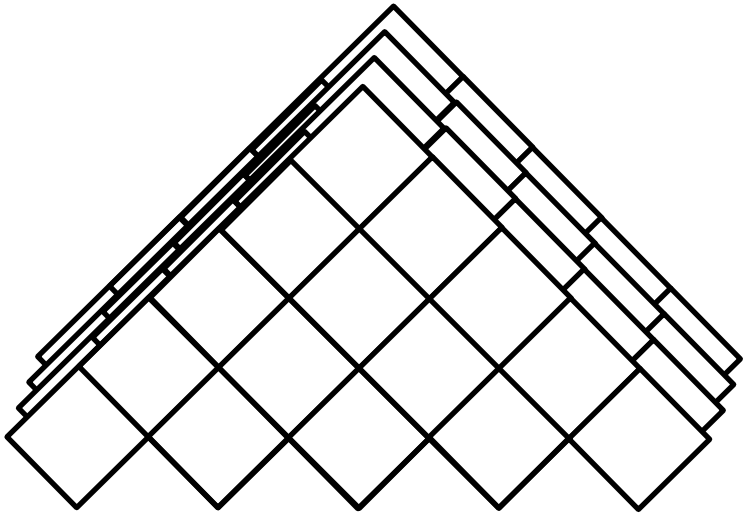
(1, 2, 4)

~~(1, 3, 4)~~

⋮

GPU





Parsing Speed