Natural Language Processing

Lecture 14—3/2/2015

Martha Palmer

Today

- Start on Parsing
  - Top-down vs. Bottom-up
  - CKY

Top-down vs. Bottom-up

- Helps with POS ambiguities – only consider relevant POS
- Rebuilds the same structure repeatedly
- Spends a lot of time on impossible parses (trees that are not consistent with any of the words)

- Has to consider every POS
- Builds each structure once
- Spends a lot of time on useless structures (trees that make no sense globally)

What would be better?

Dynamic Programming

- DP search methods fill tables with partial results and thereby
  - Avoid doing avoidable repeated work
  - Solve exponential problems in polynomial time
  - Efficiently store ambiguous structures with shared sub-parts.
- We'll cover two approaches that roughly correspond to top-down and bottom-up approaches.
  - CKY
  - Earley

CKY Parsing

- First we'll limit our grammar to epsilon-free, binary rules
- Consider the rule $A \rightarrow BC$
  - If there is an A somewhere in the input generated by this rule then there must be a B followed by a C in the input.
  - If the A spans from i to j in the input then there must be some k st. i<k<j
    - In other words, the B splits from the C someplace after the i and before the j.

Grammar rules in CNF

$S \rightarrow Aux\ NP\ VP$	$S \rightarrow X1\ VP$
	$X1 \rightarrow Aux\ NP$
$S \rightarrow VP$	$S \rightarrow book \mid include \mid prefer$
	$S \rightarrow Verb\ NP$
	$S \rightarrow X2\ PP$
	$S \rightarrow Verb\ PP$
	$S \rightarrow VP\ PP$
$NP \rightarrow Pronoun$	$NP \rightarrow I \mid she \mid me$
$NP \rightarrow Proper\text{-}Noun$	$NP \rightarrow TWA \mid Houston$
$NP \rightarrow Det\ Nominal$	$NP \rightarrow Det\ Nominal$
$Nominal \rightarrow Noun$	$Nominal \rightarrow book \mid flight \mid meal \mid money$
$Nominal \rightarrow Nominal\ Noun$	$Nominal \rightarrow Nominal\ Noun$
$Nominal \rightarrow Nominal\ PP$	$Nominal \rightarrow Nominal\ PP$
$VP \rightarrow Verb$	$VP \rightarrow book \mid include \mid prefer$
$VP \rightarrow Verb\ NP$	$VP \rightarrow Verb\ NP$
$VP \rightarrow Verb\ NP\ PP$	$VP \rightarrow X2\ PP$
	$X2 \rightarrow Verb\ NP$
$VP \rightarrow Verb\ PP$	$VP \rightarrow Verb\ PP$

CKY

- Let's build *a table* so that an *A* spanning from i to j in the input is placed in cell [i,j] in the table.
  - So a non-terminal spanning an entire string will sit in cell [0, n]
    - Hopefully it will be an *S*
- Now we know that the parts of the A must go from i to k and from k to j, for some k

CKY

- Meaning that for a rule like A → B C we should look for a B in [i,k] and a C in [k,j].
- In other words, if we think there might be an A spanning i,j in the input… AND

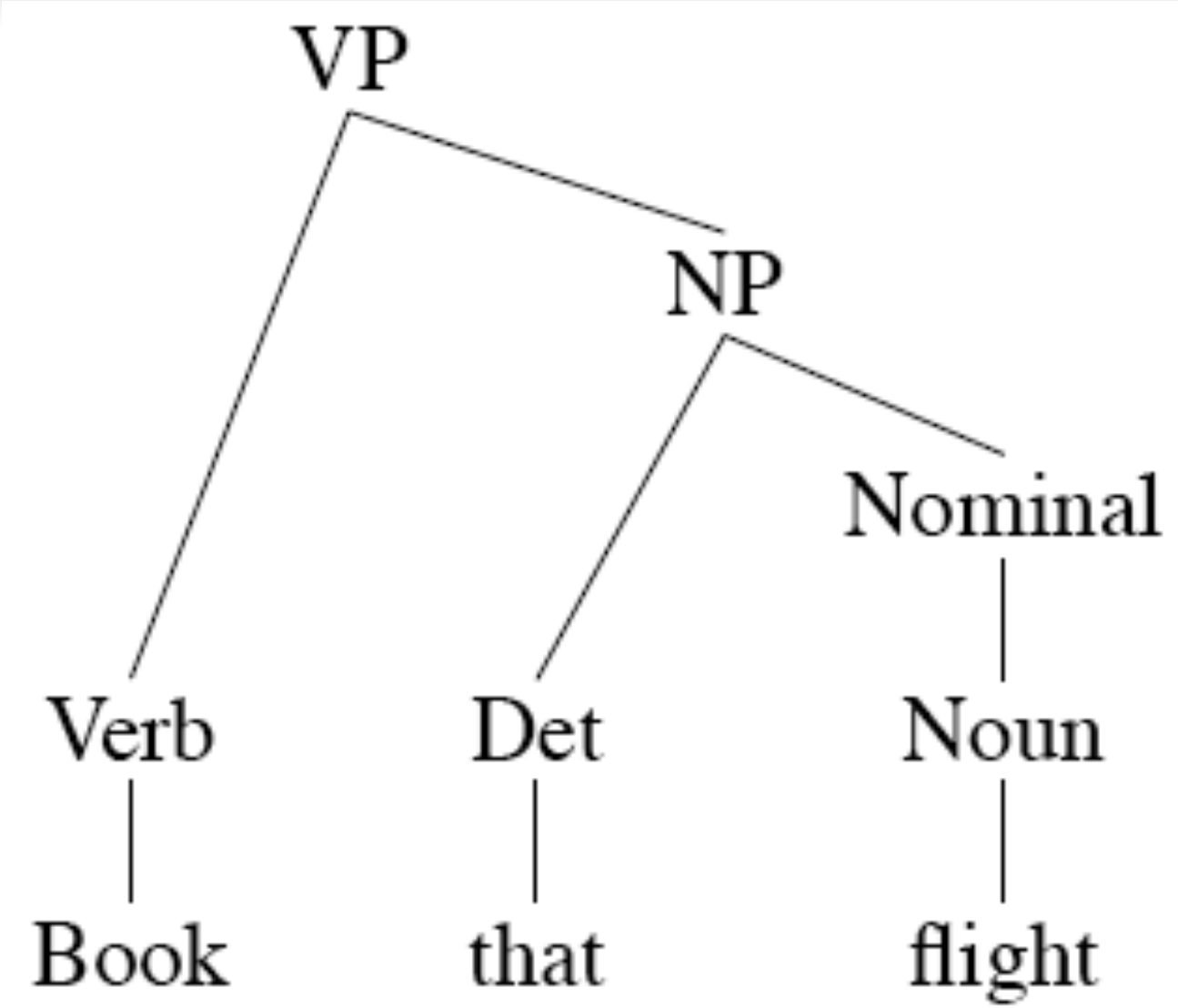
  A → B C is a rule in the grammar THEN
- There must be a B in [i,k] and a C in [k,j] for some k such that i<k<j

What about the B and the C?

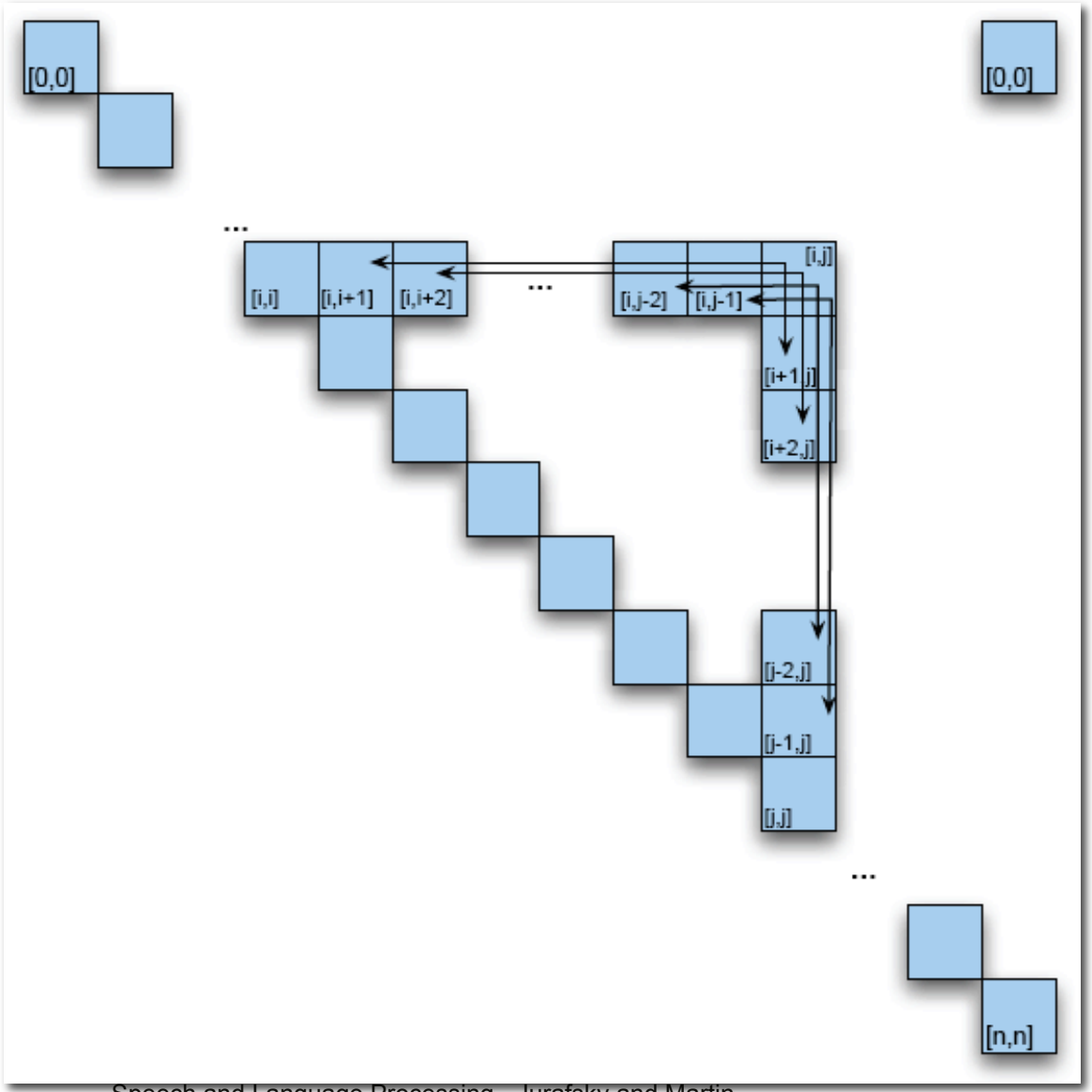
CKY

- So to fill the table loop over the cell [i,j] values in some systematic way
  - Then for each cell, loop over the appropriate k values to search for things to add.
  - Add all the derivations that are possible for each [i,j] for each k

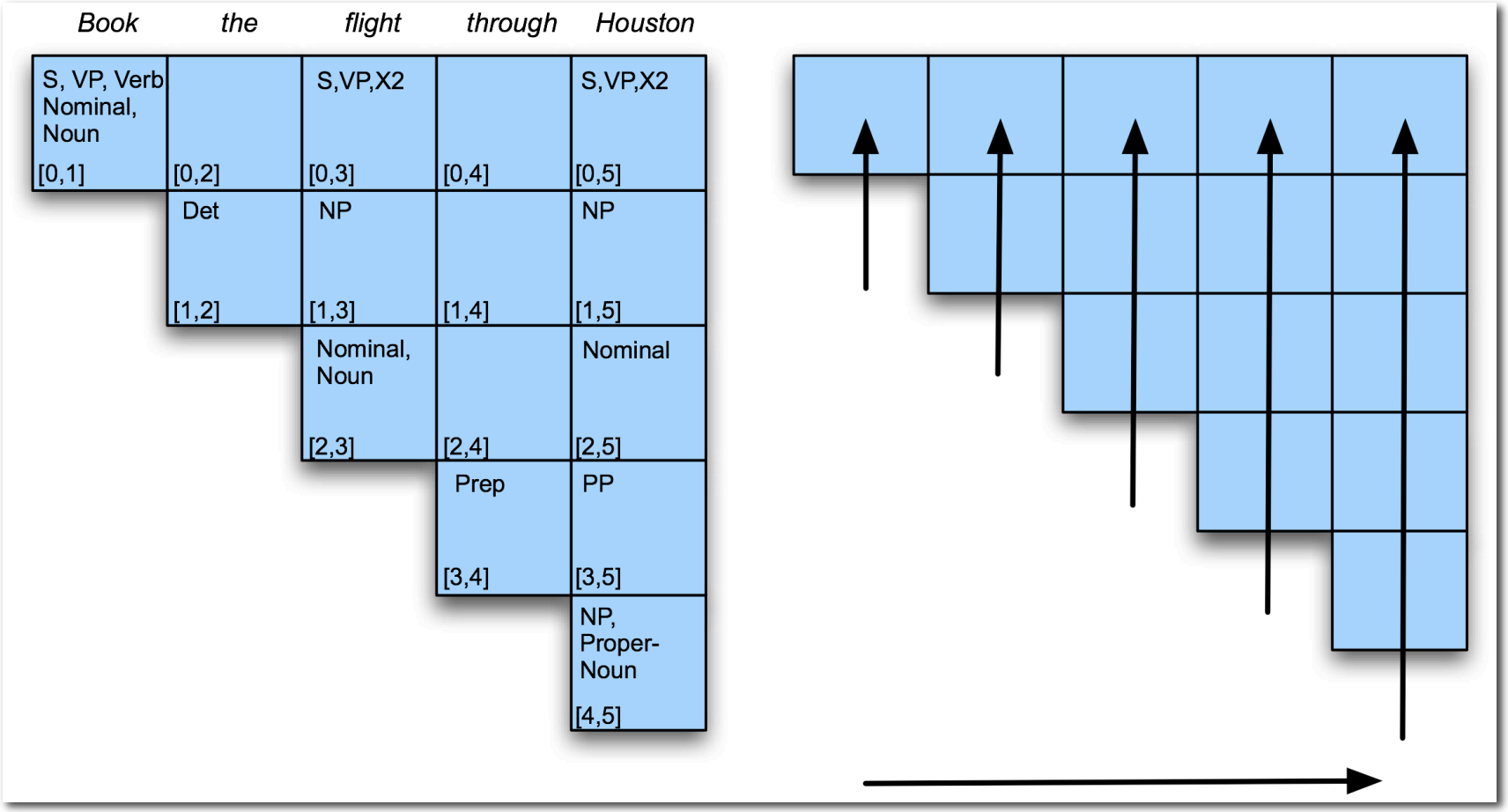
Bottom-Up Search



CKY Table



Example


Book
the
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S, VP, Verb Nominal, Noun
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CKY Algorithm

function CKY-PARSE(*words*, *grammar*) **returns** *table*

for $j \leftarrow$ **from** 1 **to** LENGTH(*words*) **do**
  $table[j-1, j] \leftarrow \{A \mid A \rightarrow words[j] \in grammar\}$
  for $i \leftarrow$ **from** $j-2$ **downto** 0 **do**
    for $k \leftarrow i+1$ **to** $j-1$ **do**
      $table[i,j] \leftarrow table[i,j] \cup$
        $\{A \mid A \rightarrow BC \in grammar,$
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Looping over the columns

Filling the bottom cell

Filling row i in column j

Looping over the possible split locations between i and j.

Check the grammar for rules that link the constituents in [i,k] with those in [k,j]. For each rule found store the LHS of the rule in cell [i,j].

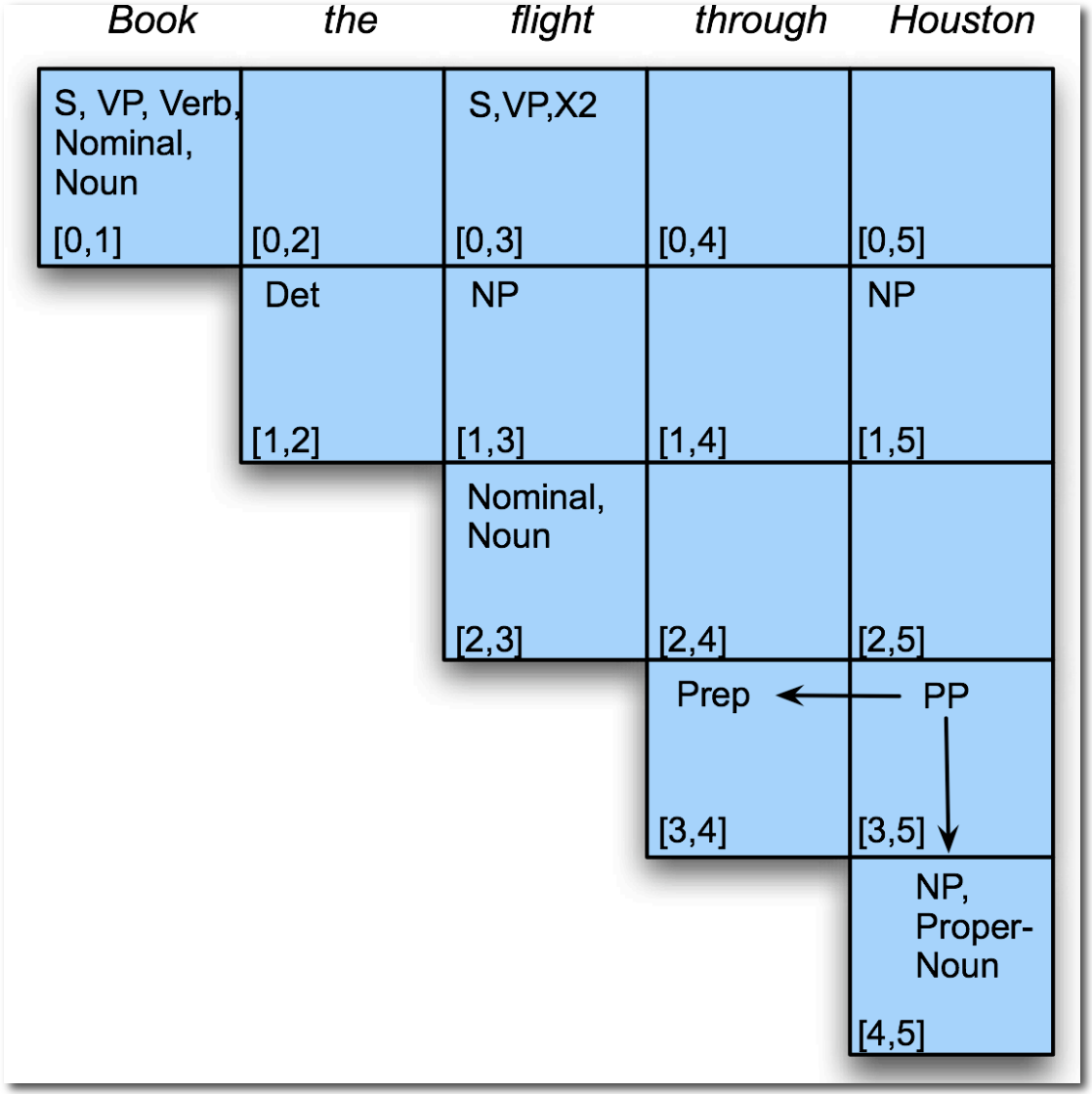
Example

- Filling column 5 corresponds to processing word 5, which is *Houston*.
  - So *j* is 5.
  - So *i* goes from 3 to 0 (3,2,1,0)

```
function CKY-PARSE(words, grammar) returns table

  for j ← from 1 to LENGTH(words) do
      table[j − 1, j] ← {A | A → words[j] ∈ grammar}
      for i ← from j − 2 downto 0 do
          for k ← i + 1 to j − 1 do
              table[i,j] ← table[i,j] ∪
                           {A | A → BC ∈ grammar,
                                B ∈ table[i,k],
                                C ∈ table[k, j]}
```

Example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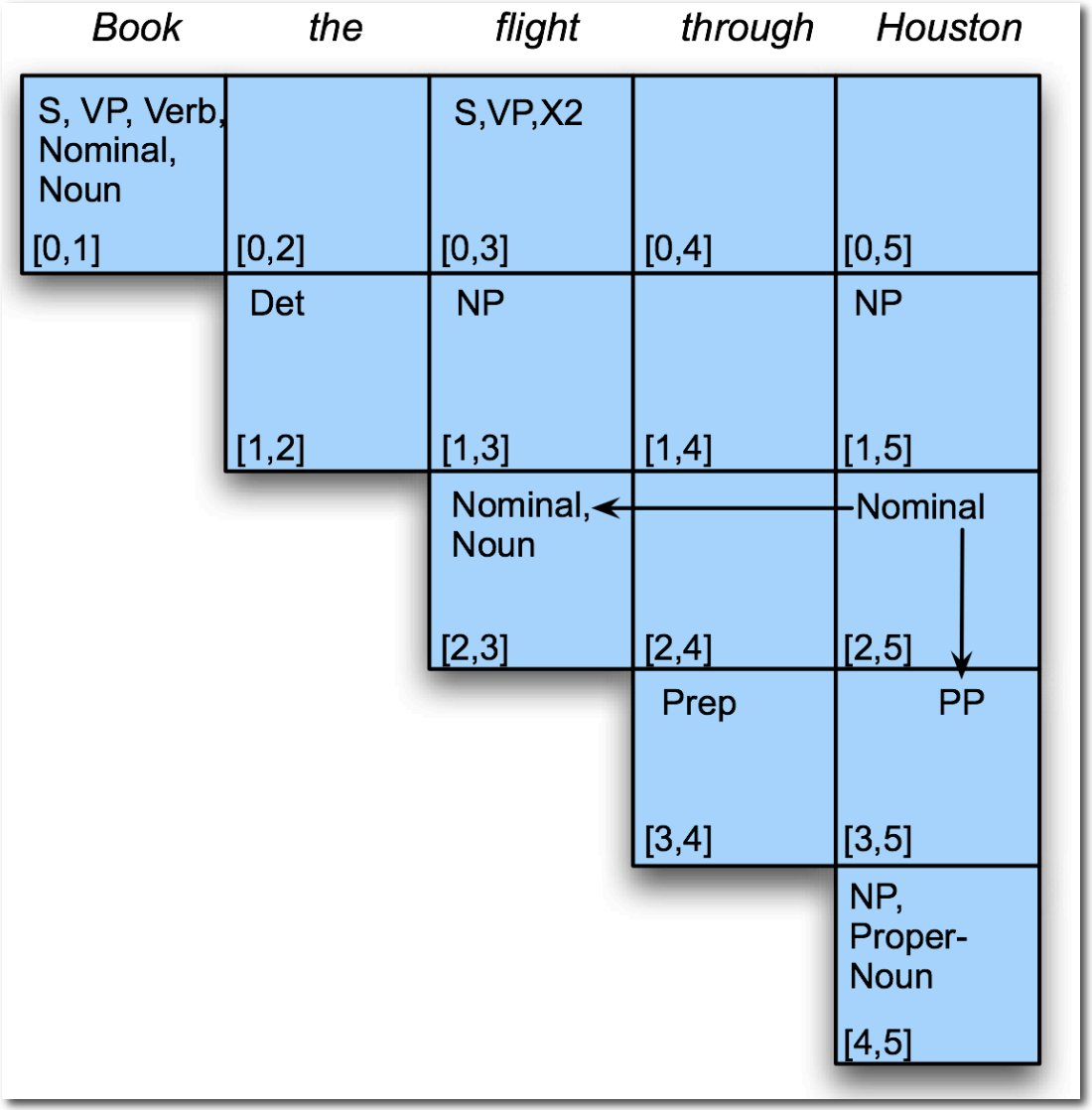
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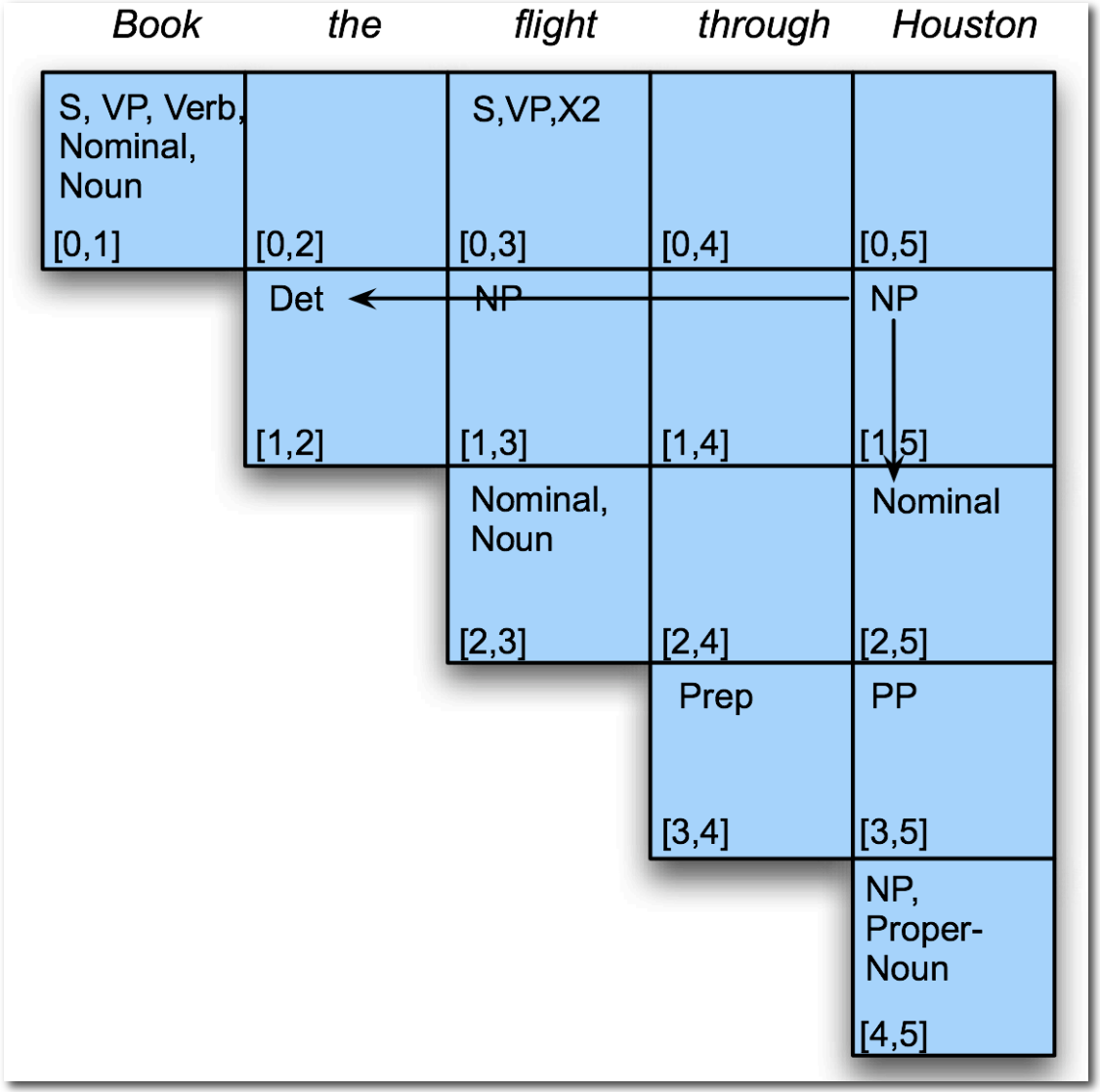
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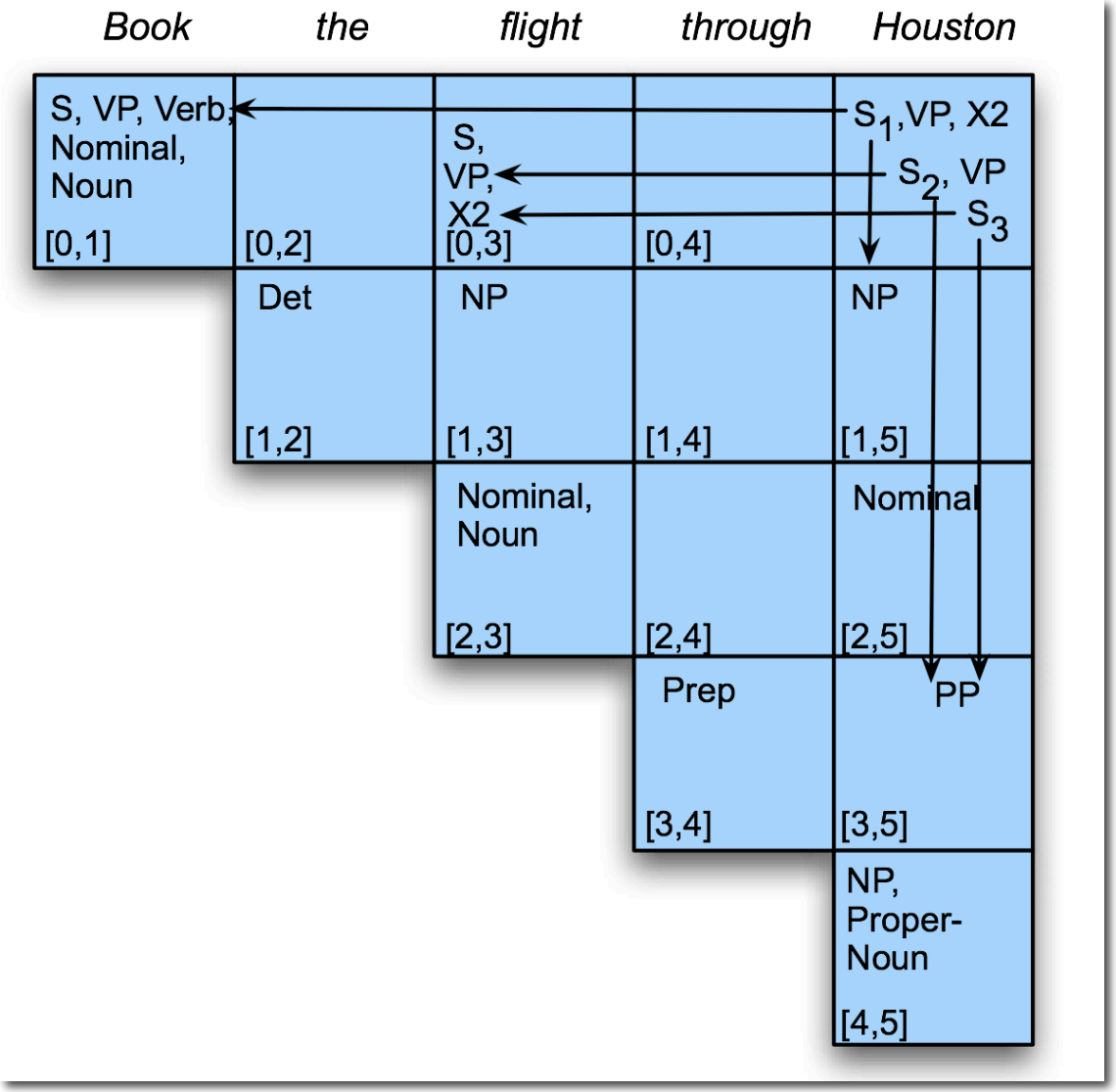
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Example

- Since there's an *S* in [0,5] we have a valid parse.
- Are we done? Well, we sort of left something out of the algorithm

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CKY Notes

- Since it's bottom up, CKY hallucinates a lot of silly constituents.
  - Segments that by themselves are constituents but cannot really occur in the context in which they are being suggested.
  - To avoid this we can switch to a top-down control strategy
  - Or we can add some kind of filtering that blocks constituents where they can not happen in a final analysis.

CKY Notes

- We arranged the loops to fill the table a column at a time, from left to right, bottom to top.
  - This assures us that whenever we're filling a cell, the parts needed to fill it are already in the table (to the left and below)
  - It's somewhat natural in that it processes the input left to right a word at a time
    - Known as online
  - Can you think of an alternative strategy?

Projects

- Project Proposals due March 12

- 1 page writeup of topic and approach, + citations of selected papers, with 1 partner

- Mohammed & Yasmeen, Arabic SRL & ML
- Michael – SRL, how to integrate syntax & semantics, Luc Steels
- Matt – NLG, features, STAGES
- Oliver –German parsing, ML, IR
- Garret – deep learning for Speech Recognition
- Nelson – Speech recognition, Mari Olsen UW, use of NLP?, Nuance

- Melissa & Nima, text and images, automatic captioning
- Kinjal – OFFICE
- Harsha – nlp for social media, Google multlingual POS tagging and parsing (universal)
- Betty – IR, twitter, facebook
- Rick – MT, how to scale up
- Megan – writing a grammar – German,
- Sarah – speech, comparing models

- Keyla – speech recognition w/ Garrett
- Ryan – vector space models, NYU convolutional neural network, grammar induction
- Audrey w/ Megan – temporal realtions
- Allison –NLP for sociolinguistics research
- Ross - word prediction
- Megan w/ Audrey – bioinformatics

Makeup Exam

- March 16, Monday , 12 – 1:15