2.7 语法解析（上）

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上海交大电院

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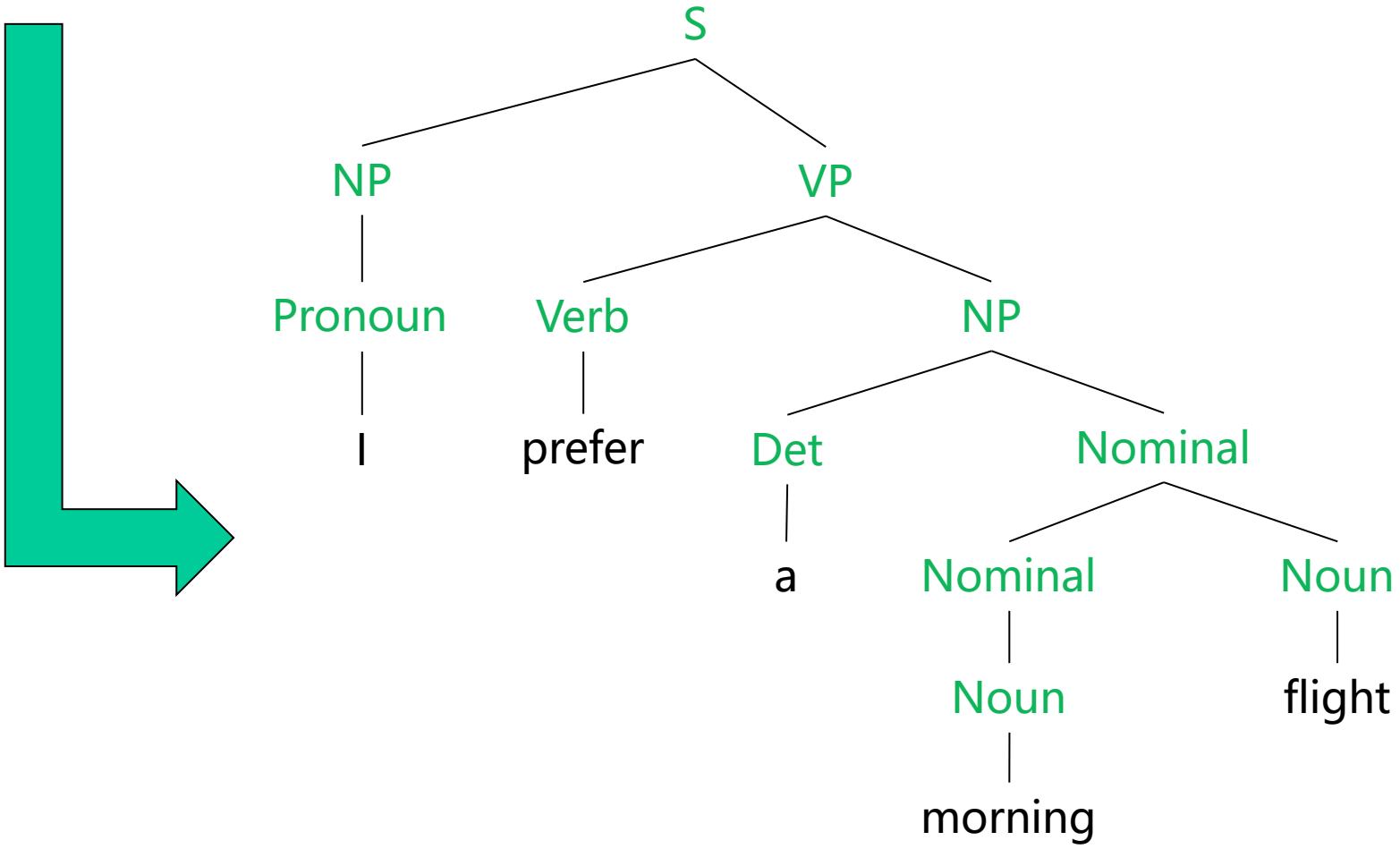
目录

目录

构成式语法（constituency grammar）简介

I prefer a morning flight.



构成式语法（constituency grammar）简介

语法成分（constituent）

句子中的一组词，作为整体可以当做一个单独的语法单元

例如：名词性短语（NP），动词性短语（VP）……

语法规则（rules）

一组描述某个语法成分可以由什么组成的规则。

例如：

NP → Det Nominal（名词性短语可以由冠词加名词构成）
NP → ProperNoun（名词性短语可以专有名词构成）

词典（lexicon）

一组描述某个语法成分可以由什么词来构成的规则。

例如：

Det → a | an | the
Noun → flight | duck | paper

构成式语法（constituency grammar）简介

语法成分（constituent）

S(句子)
NP(名词性短语)
VP(动词性短语)
Pronoun(代词)
Proper-Noun(专有名词)
Det(冠词)
Nominal(名词性成分)
Verb(动词)
PP(介词短语)
Preposition(介词)

语法规则（rules）

S → NP VP
NP → Pronoun
NP → Proper-Noun
NP → Det Nominal
Nominal → Nominal Noun
Nominal → Noun
PP → Preposition NP
VP → Verb
VP → Verb NP
VP → Verb NP PP
VP → Verb PP

词典（lexicon）

Noun → flights | breeze | trip | morning
Verb → is | prefer | like | need | want | fly
Adjective → cheapest | non-stop | first | latest | other | direct
Pronoun → me | I | you | it
Proper-Noun → Alaska | Baltimore | Los Angeles | Chicago | United | American
Determiner → the | a | an | this | these | that
Preposition → from | to | on | near
Conjunction → and | or | but

构成式语法（constituency grammar）简介

- 语法成分（constituent）
- 语法规则（rules）
- 词典（lexicon）

S, NP, VP, Pronoun, Proper-Noun,
Det, Nominal, Verb, PP, Preposition

S

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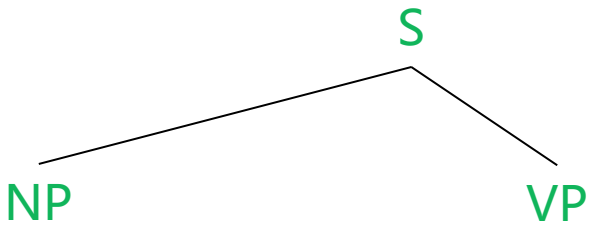

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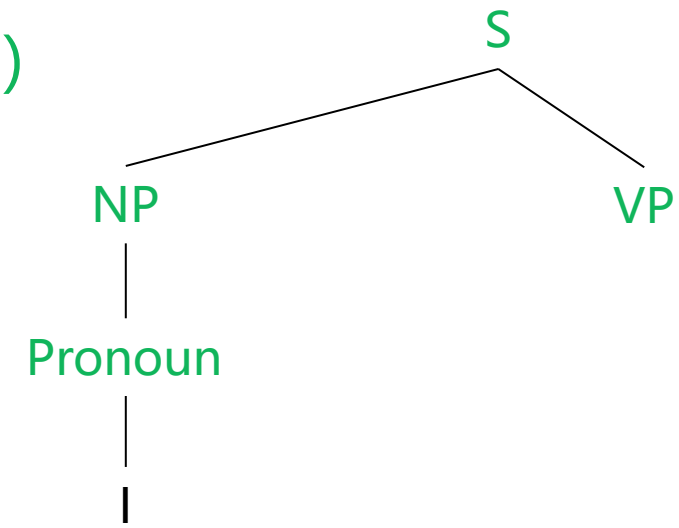

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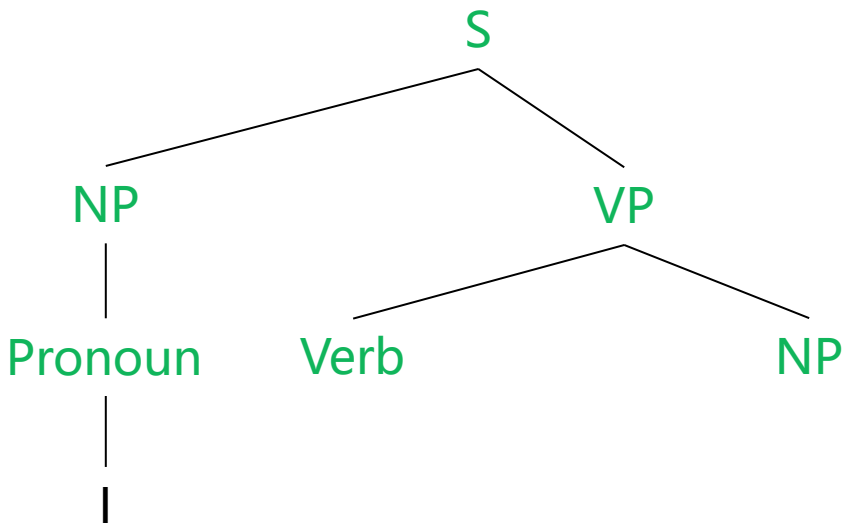

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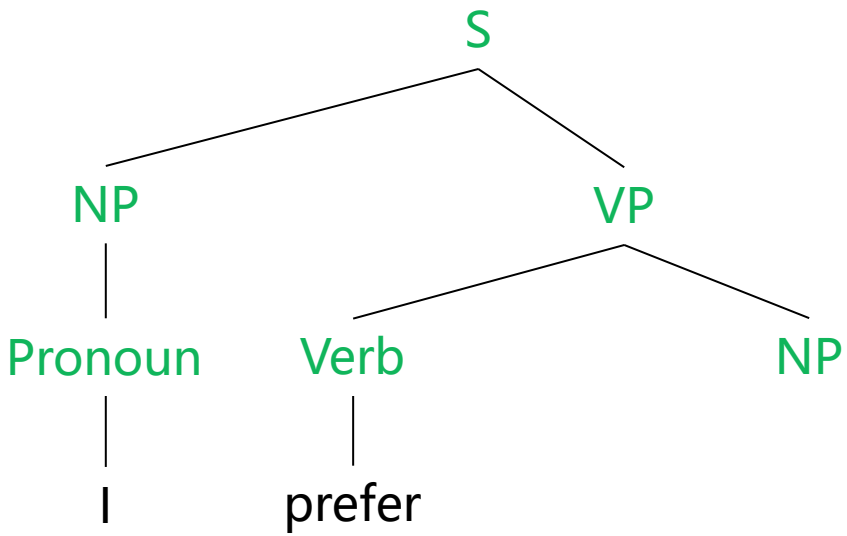

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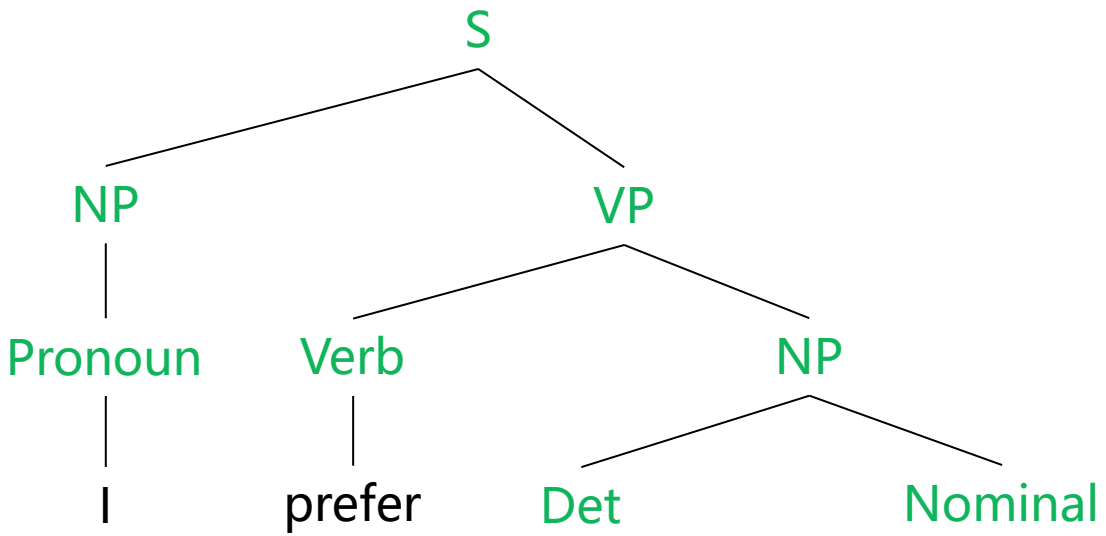

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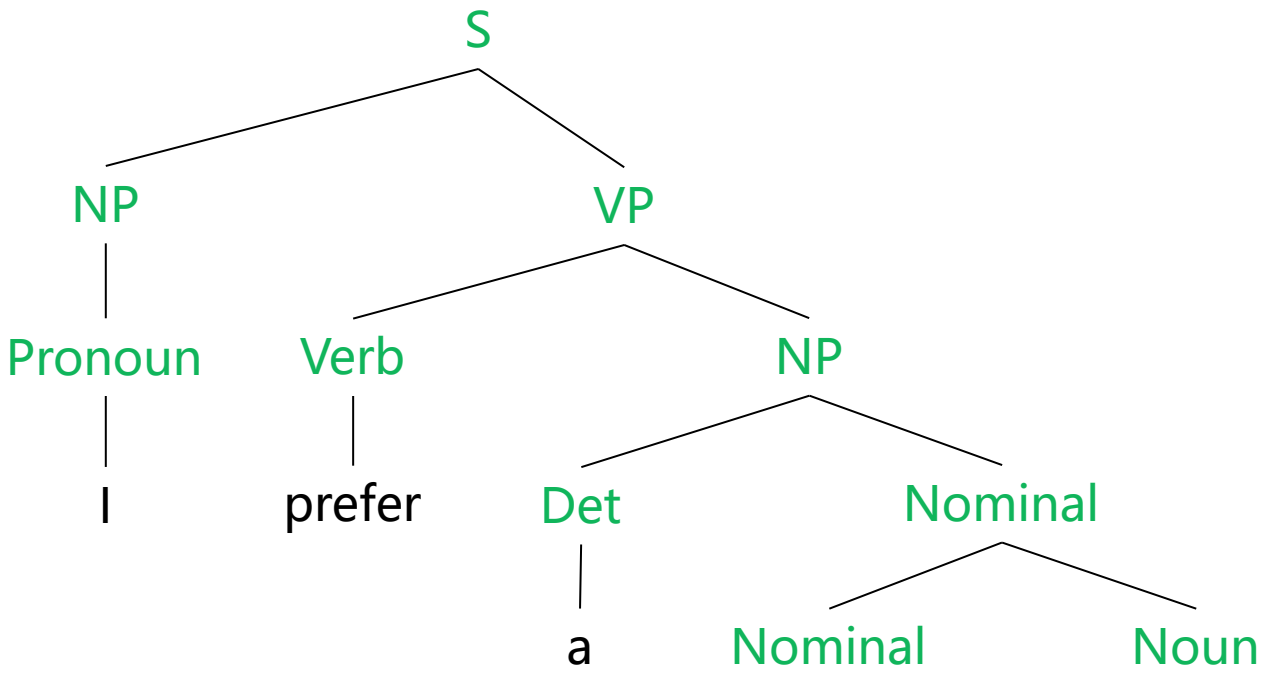

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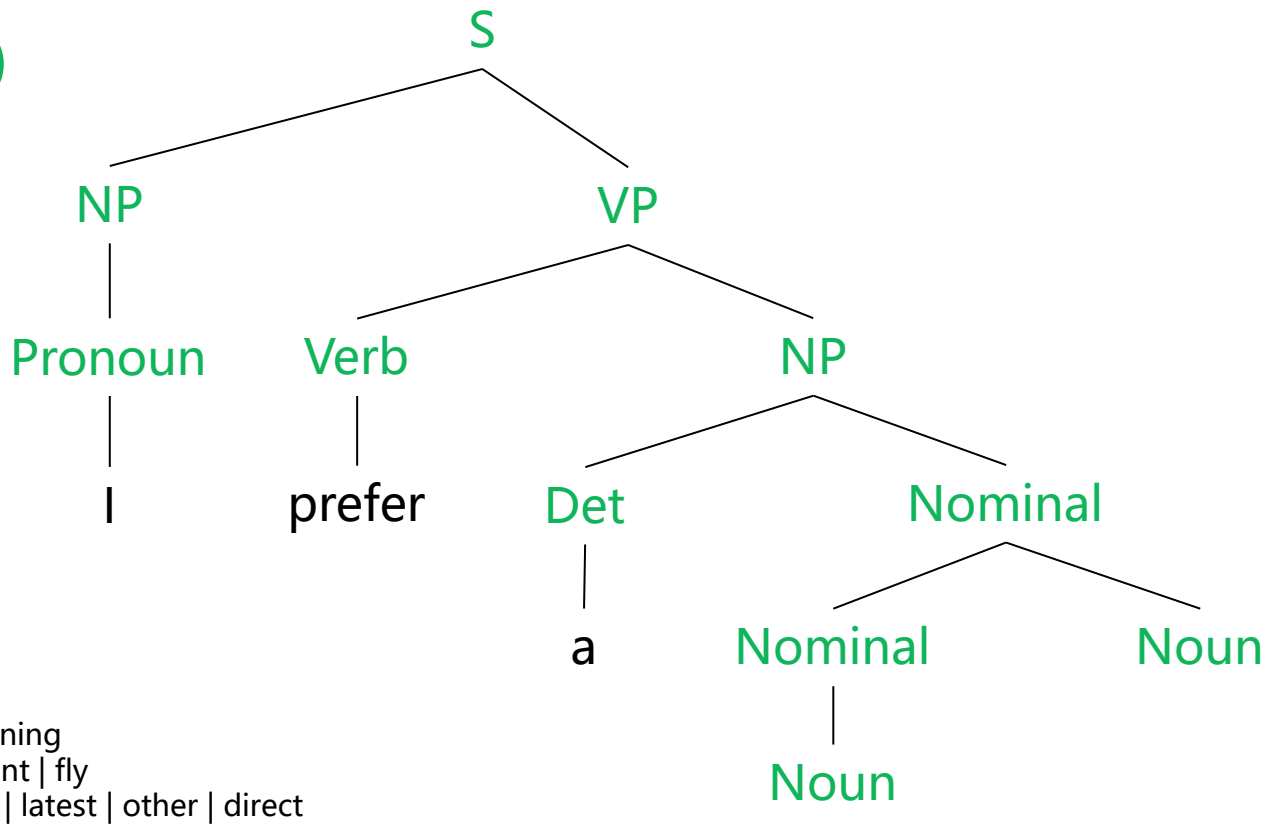

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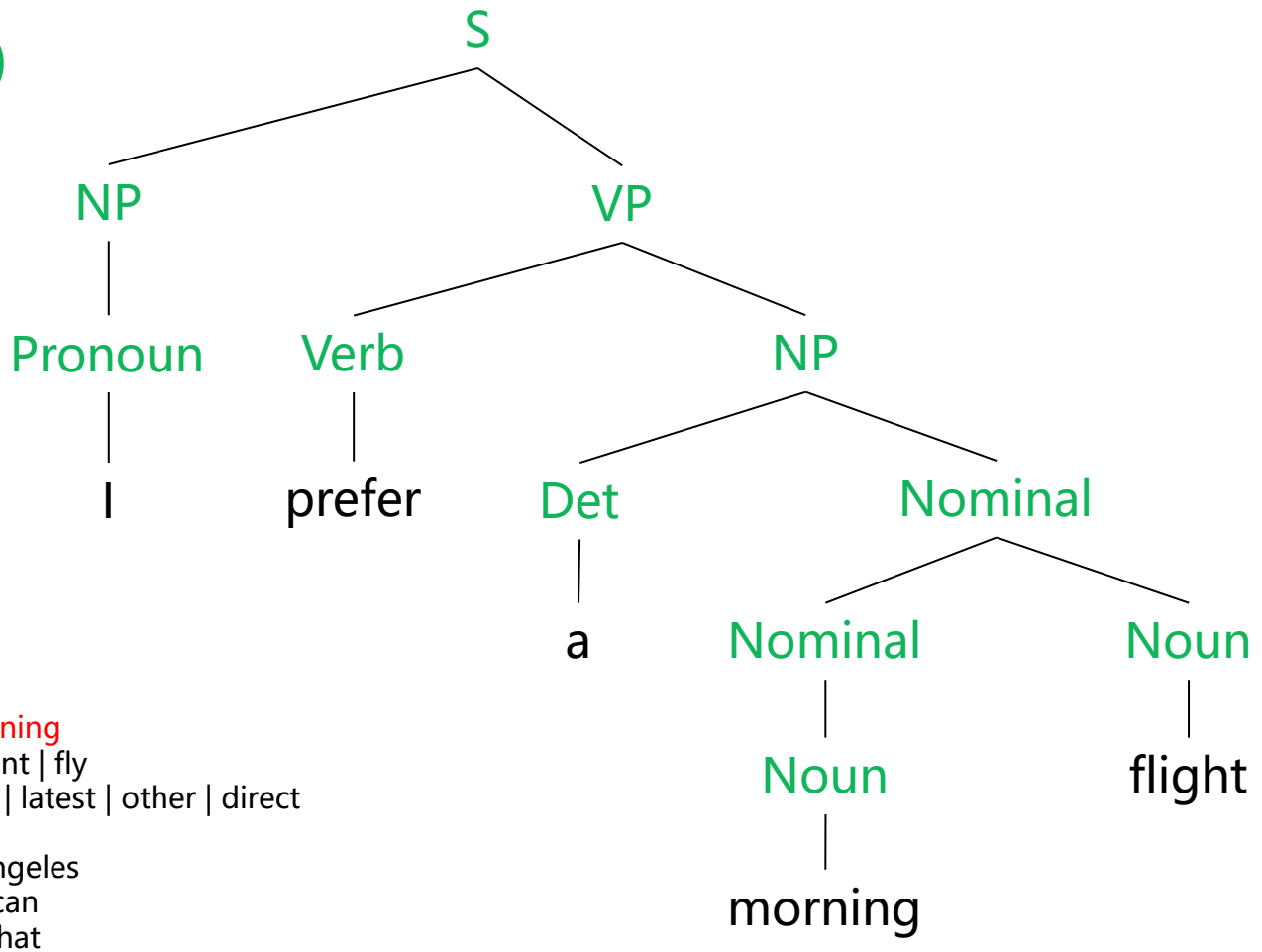

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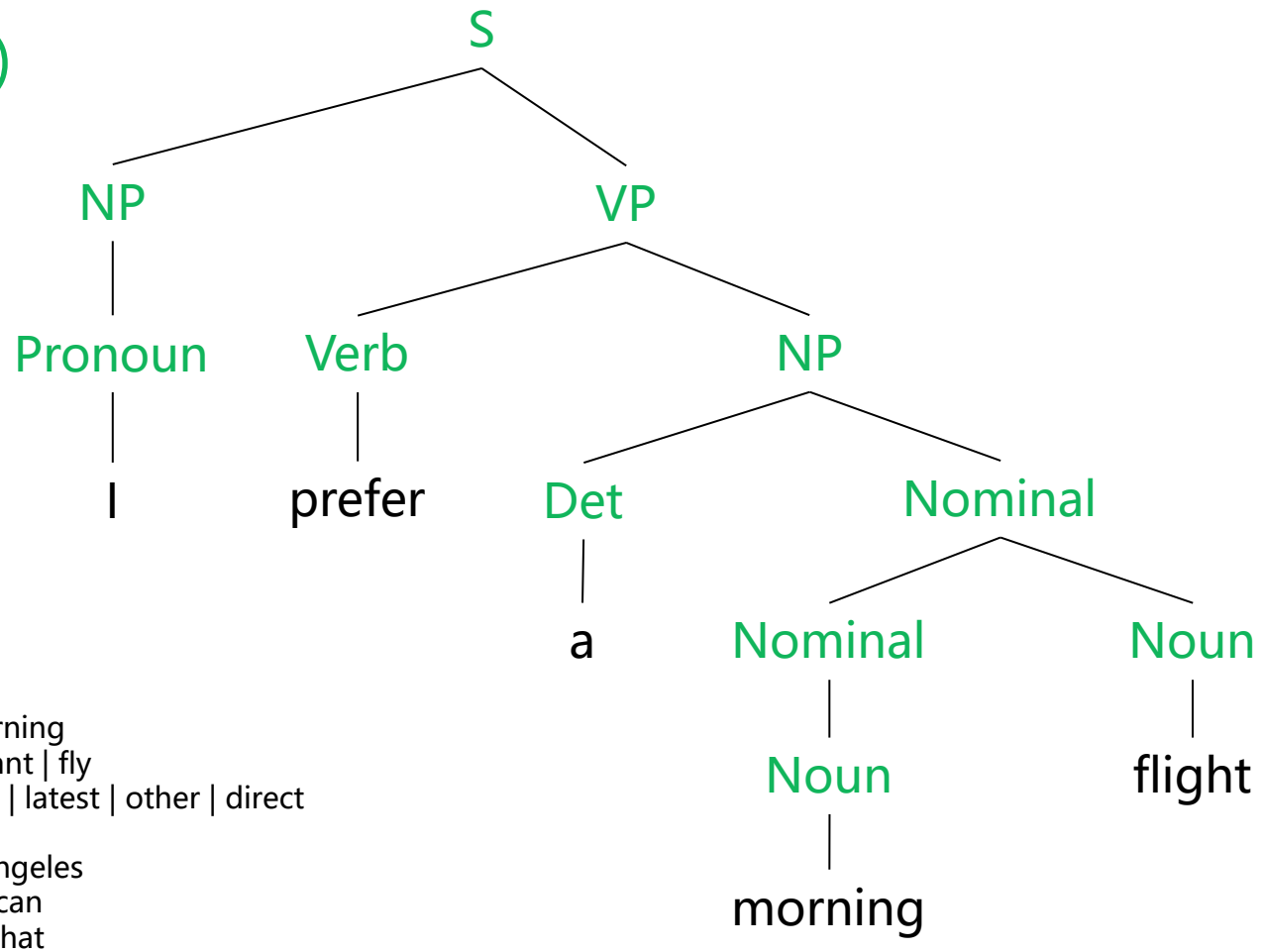

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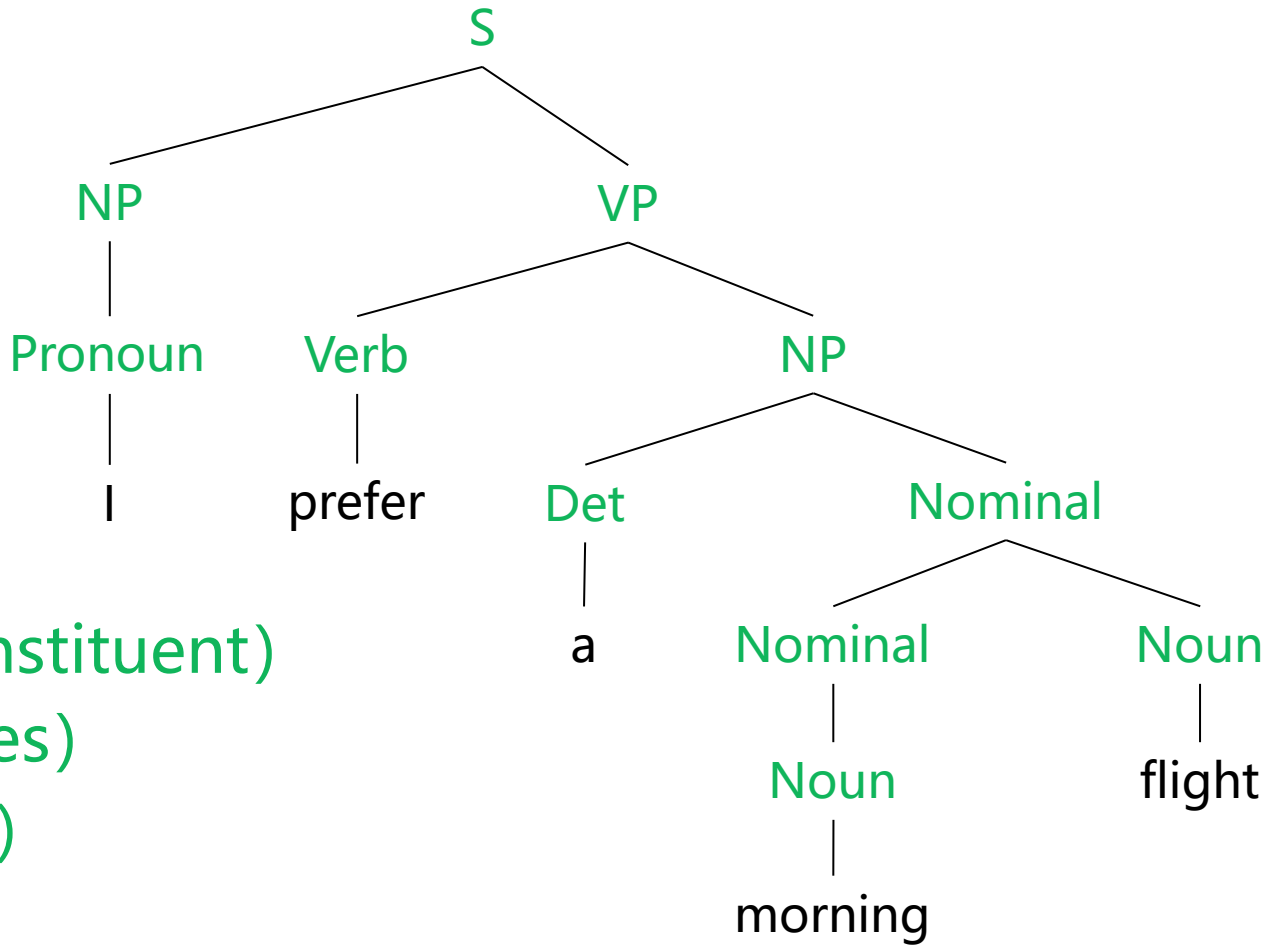
构成式语法（constituency grammar）简介

给定语法成分、语法规则和词典，我们即可由某一根节点S出发，生成语句。

- 这样的三要素的集合称为语法（grammar）；
- 能够由某一语法生成的语句，称为合乎语法的，否则称为不合乎语法的。



语法成分（constituent）
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目录

构成式语法（constituency grammar）简介

语法成分（constituent）

S(句子)	Proper-Noun(专有名词)	Verb(动词)
NP(名词性短语)	Det(冠词)	PP(介词短语)
VP(动词性短语)	Nominal(名词性成分)	Preposition(介词)
Pronoun(代词)		

N

语法规则（rules）

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Σ

R

构成式语法（constituency grammar）简介

N 一组定义好的语法成分（constituent），并且只能作为语法树中的非叶子节点（non-terminal symbols）

S(句子)　Proper-Noun(专有名词)　Verb(动词)
NP(名词性短语)　Det(冠词)　PP(介词短语)
VP(动词性短语)　Nominal(名词性成分)　Preposition(介词)
Pronoun(代词)

Σ 词汇表，只能作为语法树中的叶子节点（terminal symbols）

flights | breeze | trip | morning | is | prefer | like | need | want | fly | cheapest | non-stop | first | latest | other | direct | Pronoun | me | I | you | it | Alaska | Baltimore | Los Angeles | Chicago | United | American | the | a | an | this | these | that | Preposition | from | to | on | near | and | or | but

R 语法规则，即$\alpha \rightarrow \beta$形式的规则。α与β均可代表由$N \cup \Sigma$中的元素构成的序列

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S 语法所规定的，每个句子的根节点

CSG与CFG

上下文相关语法
(Context-sensitive Grammar，CSG)

语法树的生成与上下文相关，即：语法规则中包含“→”号左边不是单个的元素

VP NP → VP Nominal
NP NP → NP Det Nominal
prefer Pronoun PP → *prefer* Pronoun to Verb Noun
prefer NP→ *prefer* Proper-Noun

上下文无关语法
(Context-free Grammar，CFG)

语法树的生成与上下文无关，即：每一条语法规则中，“→”号左边均为单个元素

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S 语法所规定的，每个句子的根节点

从Treebanks中构建语法

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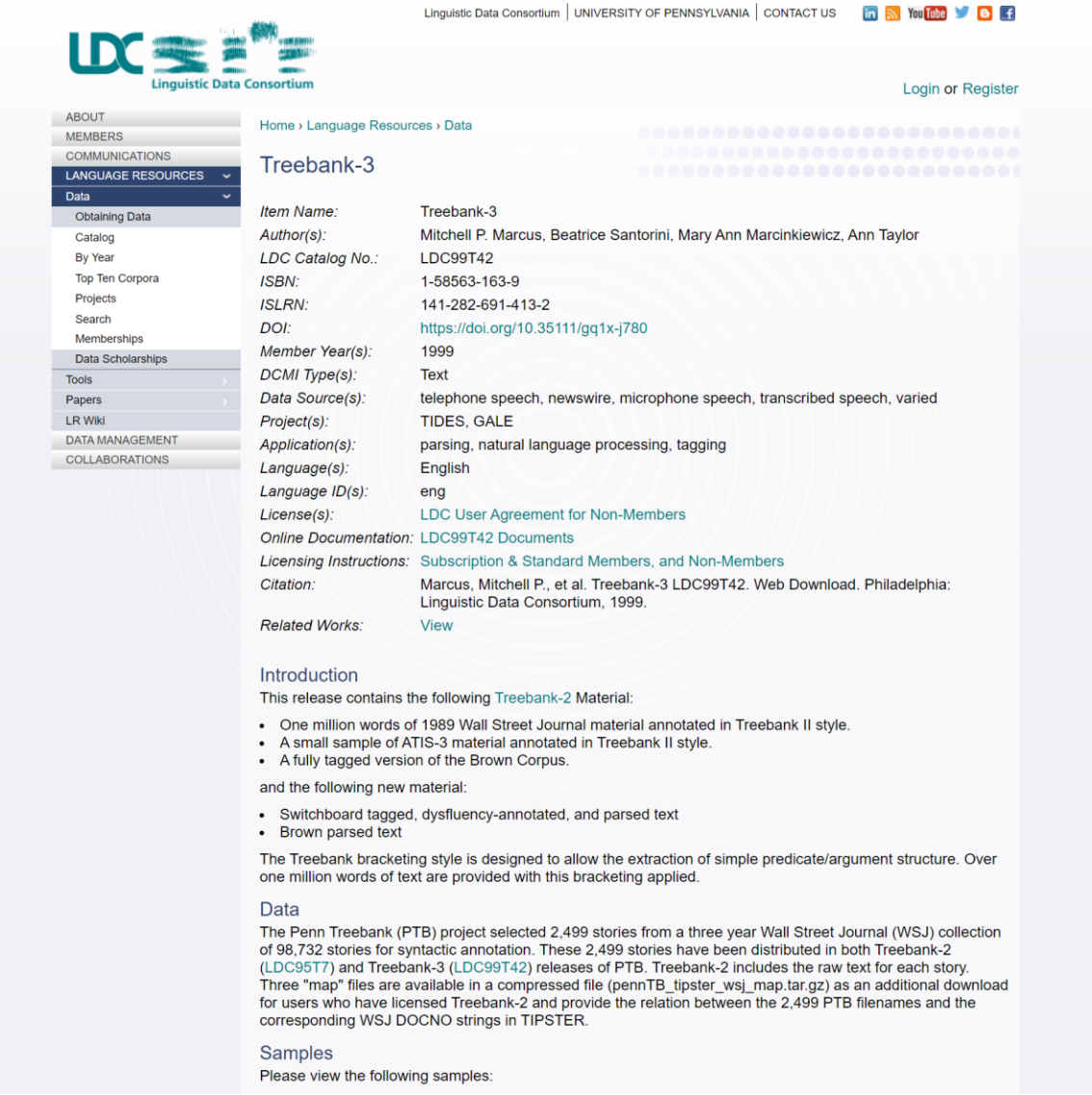
从Treebanks中构建语法：Penn Treebank语料集



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Treebank-3

Item Name:	Treebank-3
Author(s):	Mitchell P. Marcus, Beatrice Santorini, Mary Ann Marcinkiewicz, Ann Taylor
LDC Catalog No.:	LDC99T42
ISBN:	1-58563-163-9
ISLRN:	141-282-691-413-2
DOI:	https://doi.org/10.35111/gq1x-j780
Member Year(s):	1999
DCMI Type(s):	Text
Data Source(s):	telephone speech, newswire, microphone speech, transcribed speech, varied
Project(s):	TIDES, GALE
Application(s):	parsing, natural language processing, tagging
Language(s):	English
Language ID(s):	eng
License(s):	LDC User Agreement for Non-Members
Online Documentation:	LDC99T42 Documents
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Citation:	Marcus, Mitchell P., et al. Treebank-3 LDC99T42. Web Download. Philadelphia: Linguistic Data Consortium, 1999.
Related Works:	View

Introduction

This release contains the following Treebank-2 Material:

- One million words of 1989 Wall Street Journal material annotated in Treebank II style.
- A small sample of ATIS-3 material annotated in Treebank II style.
- A fully tagged version of the Brown Corpus.

and the following new material:

- Switchboard tagged, dysfluency-annotated, and parsed text
- Brown parsed text

The Treebank bracketing style is designed to allow the extraction of simple predicate/argument structure. Over one million words of text are provided with this bracketing applied.

Data

The Penn Treebank (PTB) project selected 2,499 stories from a three year Wall Street Journal (WSJ) collection of 98,732 stories for syntactic annotation. These 2,499 stories have been distributed in both Treebank-2 (LDC95T7) and Treebank-3 (LDC99T42) releases of PTB. Treebank-2 includes the raw text for each story. Three "map" files are available in a compressed file (pennTB_tipster_wsj_map.tar.gz) as an additional download for users who have licensed Treebank-2 and provide the relation between the 2,499 PTB filenames and the corresponding WSJ DOCNO strings in TIPSTER.

Samples

Please view the following samples:

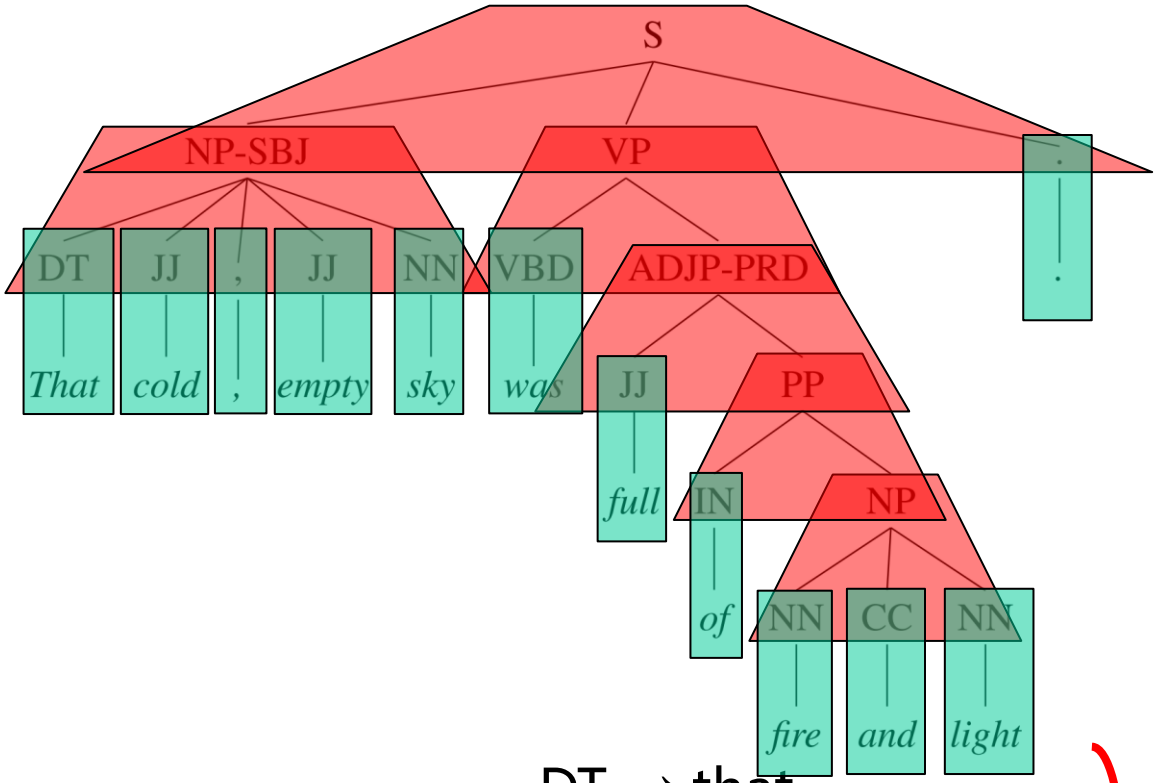
Penn treebank是宾夕法尼亚大学上世纪末收集整理的语法树数据集。

包含了从华盛顿邮报、Newswire等媒体中摘选的数万个英文语句，共约一百万个单词。并由语言学家们完成对其的语法树标注。

目前最新的treebank-3版本更新于1999年，但在语法解析领域，仍被广泛使用。

从Treebanks中构建语法：Penn Treebank语料集

```
((S
    (NP-SBJ (DT That)
      (JJ cold) (, ,)
      (JJ empty) (NN sky) )
    (VP (VBD was)
      (ADJP-PRD (JJ full)
        (PP (IN of)
          (NP (NN fire)
            (CC and)
            (NN light) ))))
    (. .) ))
```



R

NP → NN CC NN
PP → IN NP
ADJP → PRD
PRD → JJ PP

VP → VBD ADJP
SBJ → DT JJ , JJ NN
NP → SBJ
S → NP VP .

DT → that
JJ → cold | empty | full
NN → sky | fire | light
IN → of
CC → and
VBD → was
. → .
, → ,

从Treebanks中构建语法：Penn Treebank语料集

整个语料集可以收集到17500个语法规则（不包含词典部分，即上面例子中的绿色框线）。

其中，光NP的生成法则就有数千个

```
NP → DT JJ NN
NP → DT JJ NNS
NP → DT JJ NN NN
NP → DT JJ JJ NN
NP → DT JJ CD NNS
NP → RB DT JJ NN NN
NP → RB DT JJ JJ NNS
NP → DT JJ JJ NNP NNS
NP → DT NNP NNP NNP NNP JJ NN
NP → DT JJ NNP CC JJ JJ NN NNS
NP → RB DT JJS NN NN SBAR
NP → DT VBG JJ NNP NNP CC NNP
NP → DT JJ NNS , NNS CC NN NNS NN
NP → DT JJ JJ VBG NN NNP NNP FW NNP
NP → NP JJ , JJ `` SBAR '' NNS
```

……

目录

词汇化语法（lexicalized grammar）与组合范畴语法（CCG）

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事实上，某个语法成分的展开方式与具体用词息息相关。在这17500条规则中，有很大一部分是只出现了少数几次的。

```
NP → DT JJ NN
NP → DT JJ NNS
NP → DT JJ NN NN
NP → DT JJ JJ NN
NP → DT JJ CD NNS
NP → RB DT JJ NN NN
NP → RB DT JJ JJ NNS
NP → DT JJ JJ NNP NNS
NP → DT NNP NNP NNP NNP JJ NN
NP → DT JJ NNP CC JJ JJ NN NNS
NP → RB DT JJS NN NN SBAR
NP → DT VBG JJ NNP NNP CC NNP
NP → DT JJ NNS , NNS CC NN NNS NN
NP → DT JJ JJ VBG NN NNP NNP FW NNP
NP → NP JJ , JJ `` SBAR '' NNS
```

……

词汇化语法（lexicalized grammar）与组合范畴语法（CCG）

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如上的构成式语法以语法成分为中心，认为语法成分的展开是有规律可循的。

但是既然PTB上的结果告诉我们，
这样的规律也并没有那么好找，所以……

不妨反过来定义语法：以词汇为中心，对每个词定义他可以怎么用。

词汇化语法（lexicalized grammar）

词汇化语法（lexicalized grammar）：更多依赖具体词汇，认为合法的语法结构与词汇具体是什么相关。

help sb do sth
ask sb to do sth
pass sth to sb
....

词汇化语法
(lexicalized grammar)

- Lexical-Functional Grammar (LFG)
  (Bresnan, 1982)
- Head-Driven Phrase Structure Grammar (HPSG)
  (Pollard and Sag, 1994)
- Tree-Adjoining Grammar (TAG)
  (Joshi,1985)
- Combinatory Categorial Grammar (CCG)
  (Steedman 1989, Steedman 2000)

语法间的等同关系，乔姆斯基范式（CNF）

强等价：两个语法能够生成一模一样的合法语句集合，且对于同一个句子，语法结构也相同。

弱等价：两个语法能够生成一模一样的合法语句集合，但是对于同一个句子，语法结构不一定相同

CSG与CFG

上下文相关语法
(Context-sensitive Grammar，CSG)

语法树的生成与上下文相关，即：语法规则中包含“→”号左边不是单个的N中元素情况

VP NP → VP Nominal
NP NP → NP Det Nominal
prefer Pronoun PP → *prefer* Pronoun to Verb Noun
prefer NP→ *prefer* Proper-Noun

约束R中规则的形式

上下文无关语法
(Context-free Grammar，CFG)

语法树的生成与上下文无关，即：每一条语法规则中，“→”号左边均为单个的N中元素情况

S → NP VP
NP → Pronoun
NP → Proper-Noun
NP → Det Nominal
PP → Preposition NP
VP → Verb
VP → Verb NP
VP → Verb NP PP

R 语法规则，即$\alpha \rightarrow \beta$形式的规则。α与β均可代表由$N \cup \Sigma$中的元素构成的序列

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Noun → flights | breeze | trip | morning
Verb → is | prefer | like | need | want | fly
Adjective → cheapest | non-stop | first | latest | other | direct
Pronoun → me | I | you | it
Proper-Noun → Alaska | Baltimore | Los Angeles | Chicago | United | American
Determiner → the | a | an | this | these | that
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(Chomsky Normal Form， CNF)

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乔姆斯基范式（CNF）

乔姆斯基范式
(Chomsky Normal Form， CNF）

在CFG要求的基础上：

每条语法规则只能从一个元素生成两个元素，且不得包含单词

- √ S → NP VP
- √ NP → Det Nominal
- × NP → Pronoun
- × VP → Verb NP PP

每条词典规则只能从一个元素生成一个单词作为元素

- √ Noun → flights | breeze | trip | morning
- × Noun → New York

约束R中规则的形式

上下文无关语法
(Context-free Grammar，CFG)

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乔姆斯基范式（CNF）

乔姆斯基范式
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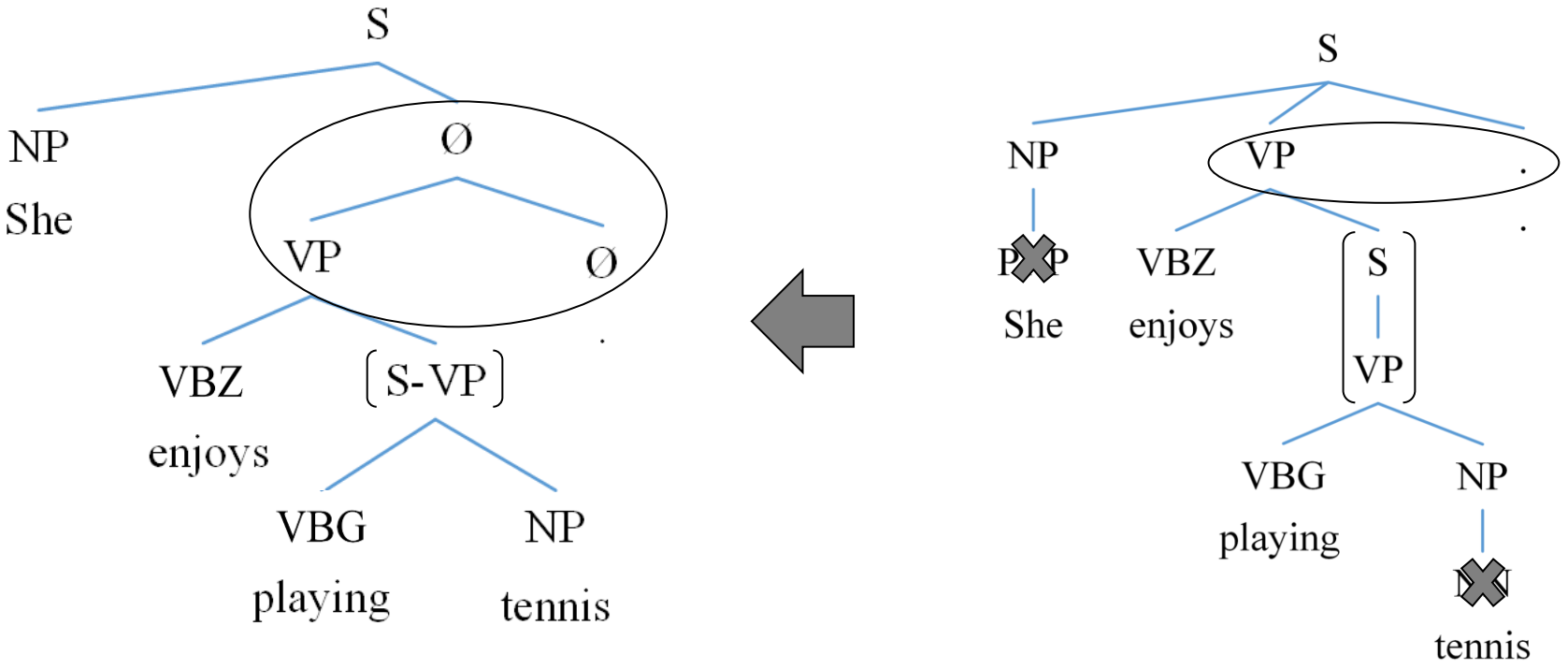
在CFG要求的基础上：

1. 每条语法规则只能从一个元素生成两个元素，且不得包含单词
2. 每条词典规则只能从一个元素生成一个单词作为元素



目录

构成式语法的语法解析算法：CKY

待解决的问题：

给定一个定义好的CNF语法，对某一句话做自动语法分析

The input string is generated by grammar

R 符合CNF的语法规则，即$A \longrightarrow B\ C$形式的语法规则，及$A \longrightarrow < word >$形式的词典规则。

S → NP VP
NP → Pronoun
NP → Proper-Noun
NP → Det Nominal
Nominal → Nominal Noun
Nominal → Noun

PP → Preposition NP
VP → Verb
VP → Verb NP
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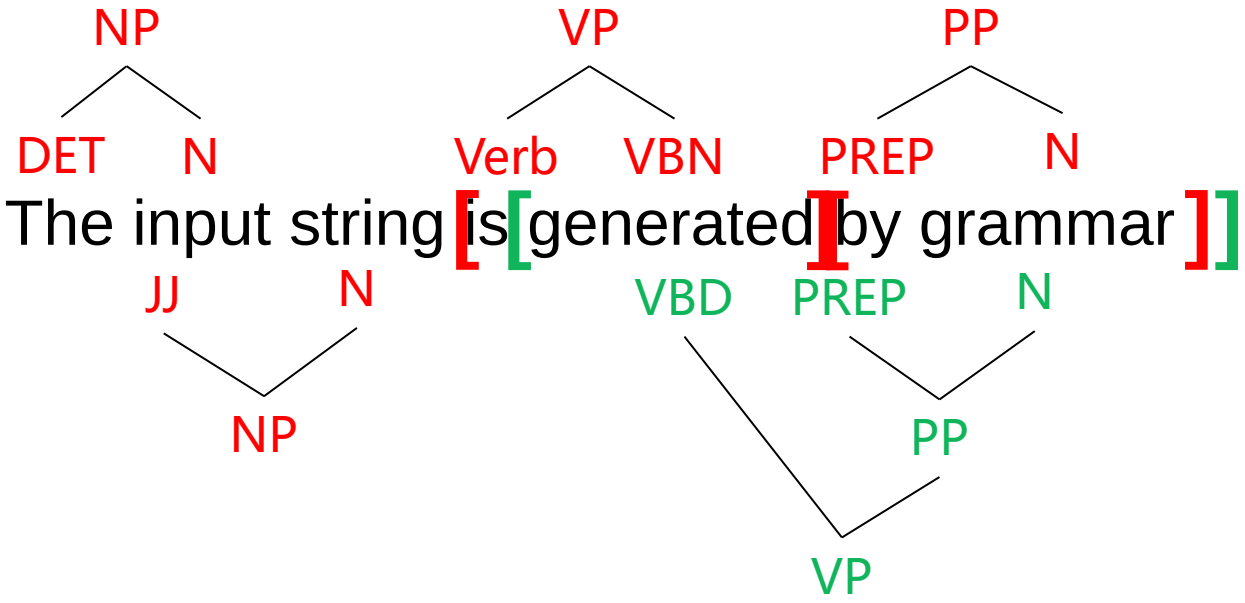


根据语法规则，找到两三个词的局部语法树相对简单；但是：

如何从所有可能的局部语法树中

——这些局部语法树之间既可能相互重叠，又可能相互矛盾——

组合出一棵能够完整构建起整个句子的全局语法树？

构成式语法的语法解析算法：CKY

例子：

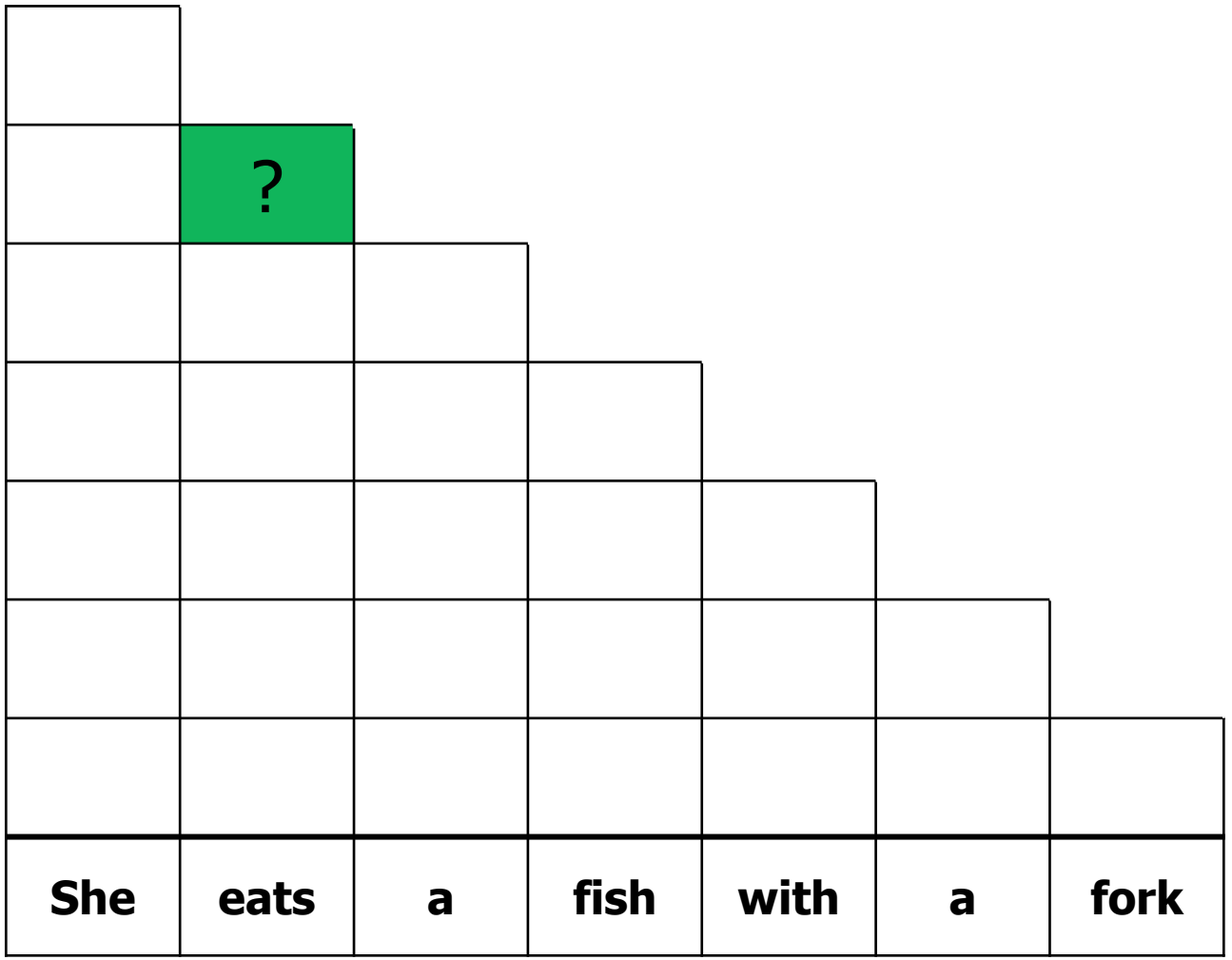
$$
\begin{aligned}
\mathrm{S} &\longrightarrow \mathrm{NP\ VP} \\
\mathrm{VP} &\longrightarrow \mathrm{VP\ PP} \\
\mathrm{VP} &\longrightarrow \mathrm{V\ NP} \\
\mathrm{PP} &\longrightarrow \mathrm{P\ NP} \\
\mathrm{NP} &\longrightarrow \mathrm{Det\ N}
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{VP} &\longrightarrow \mathrm{eats} \\
\mathrm{NP} &\longrightarrow \mathrm{she} \\
\mathrm{V} &\longrightarrow \mathrm{eats} \\
\mathrm{P} &\longrightarrow \mathrm{with} \\
\mathrm{N} &\longrightarrow \mathrm{fish} \\
\mathrm{N} &\longrightarrow \mathrm{fork} \\
\mathrm{Det} &\longrightarrow \mathrm{a}
\end{aligned}
$$

She eats a fish with a fork

构成式语法的语法解析算法：CKY

例子：



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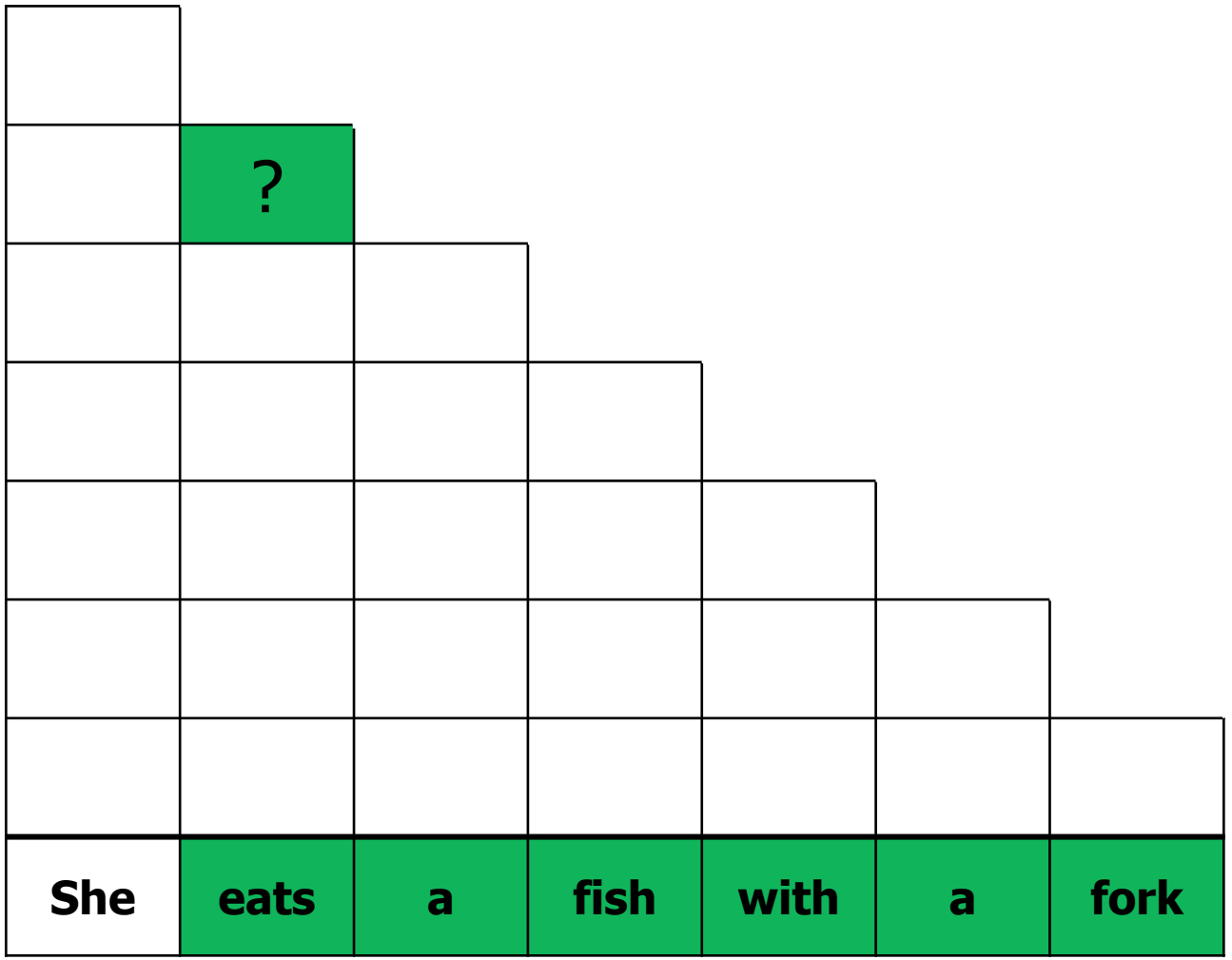

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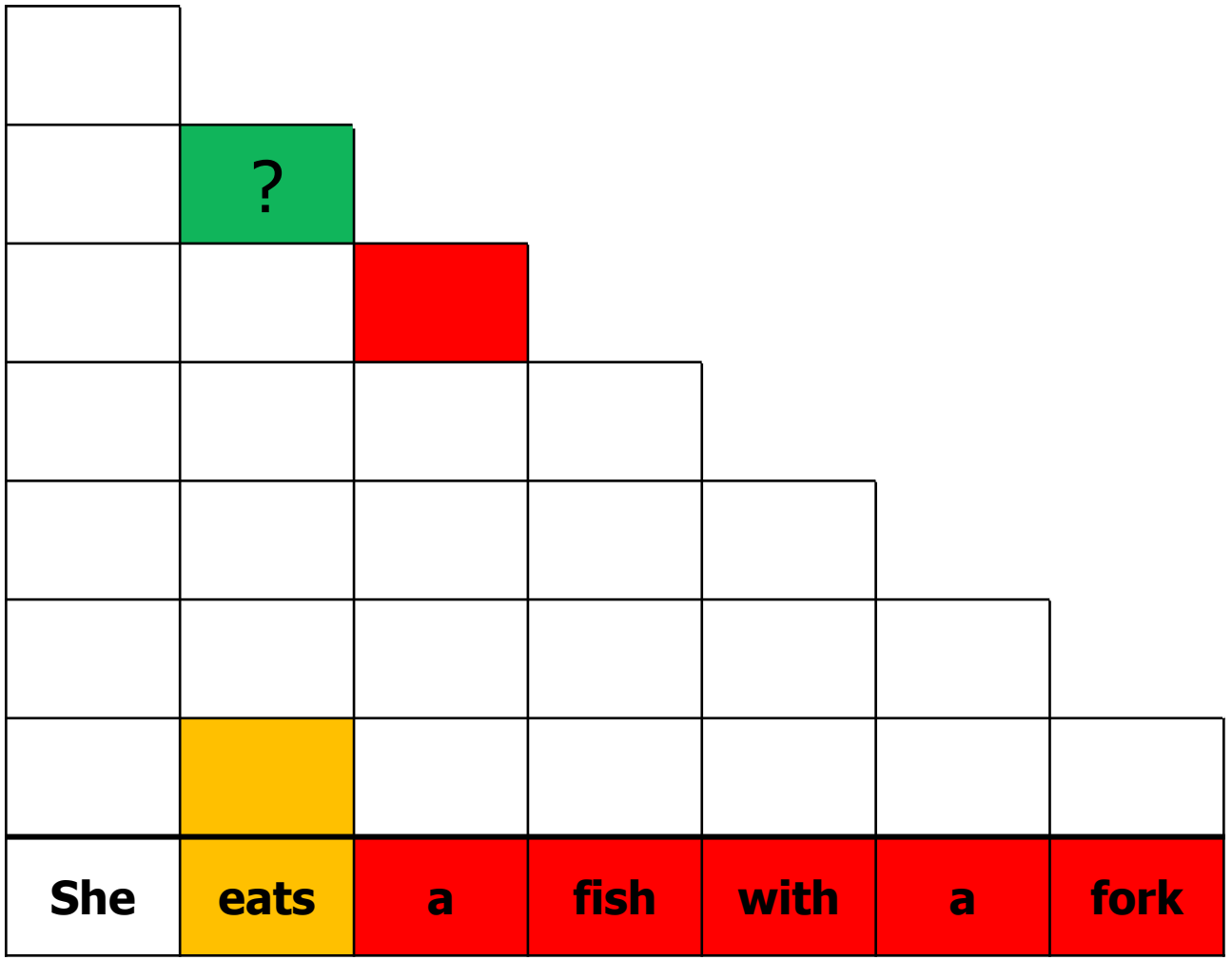

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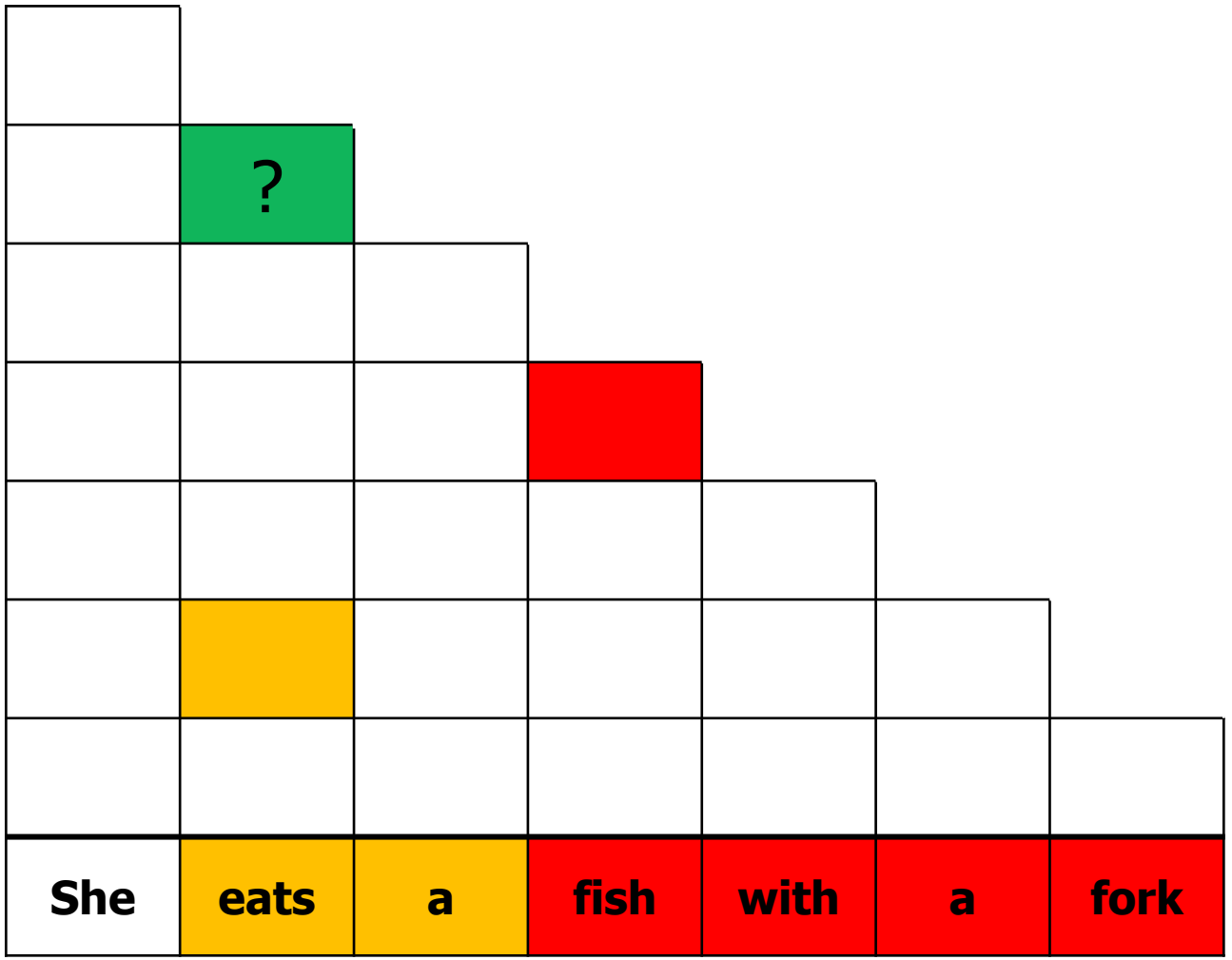

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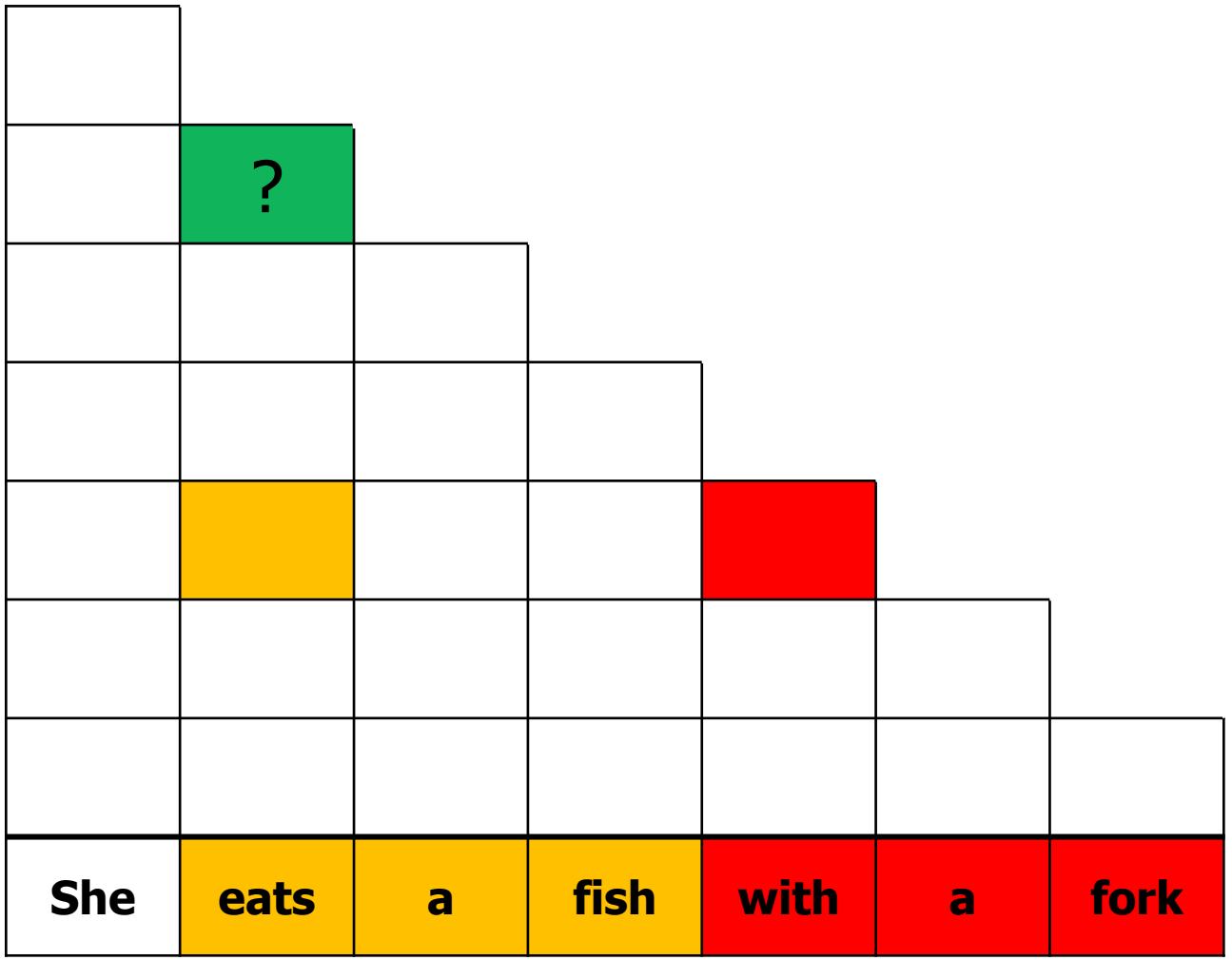

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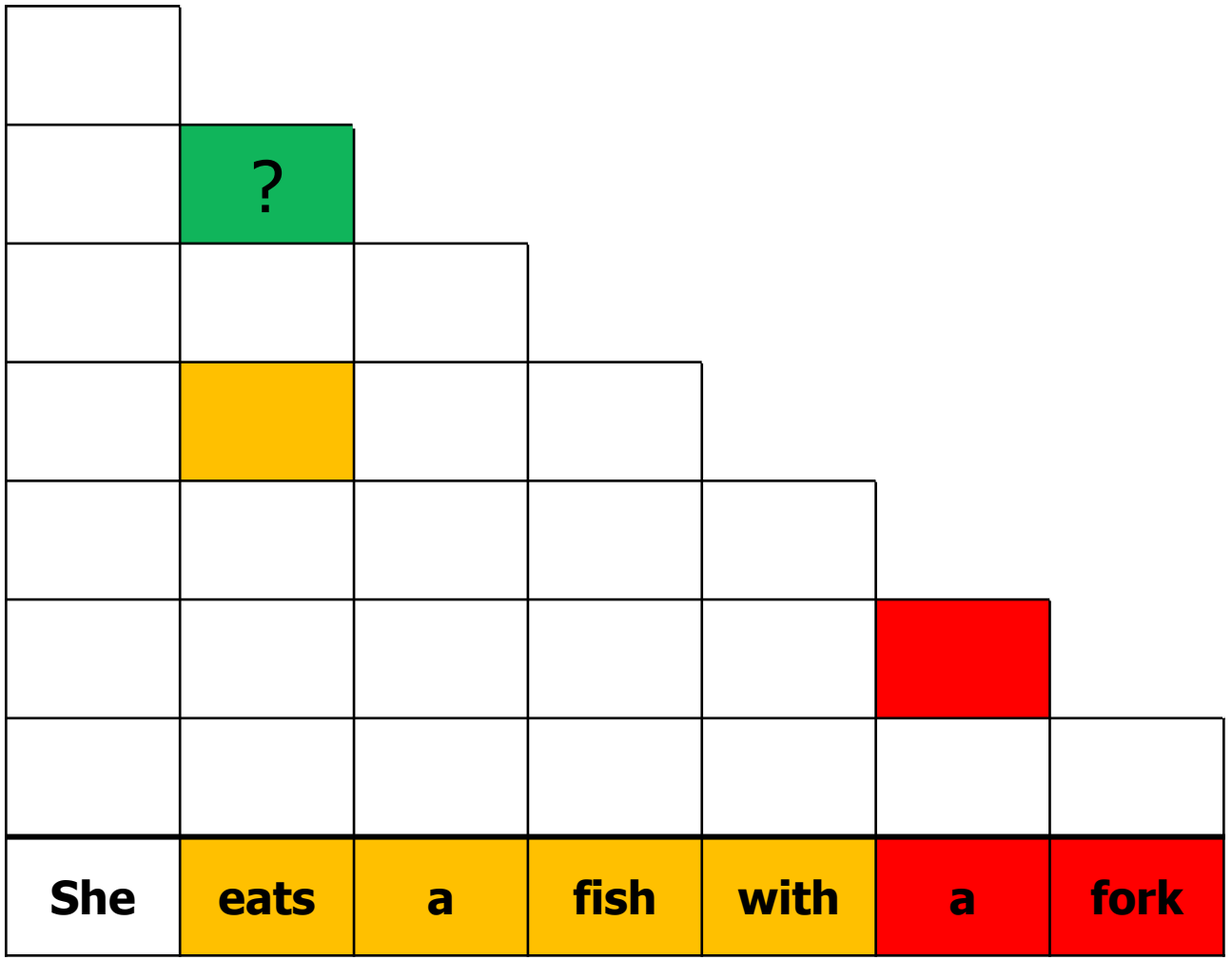

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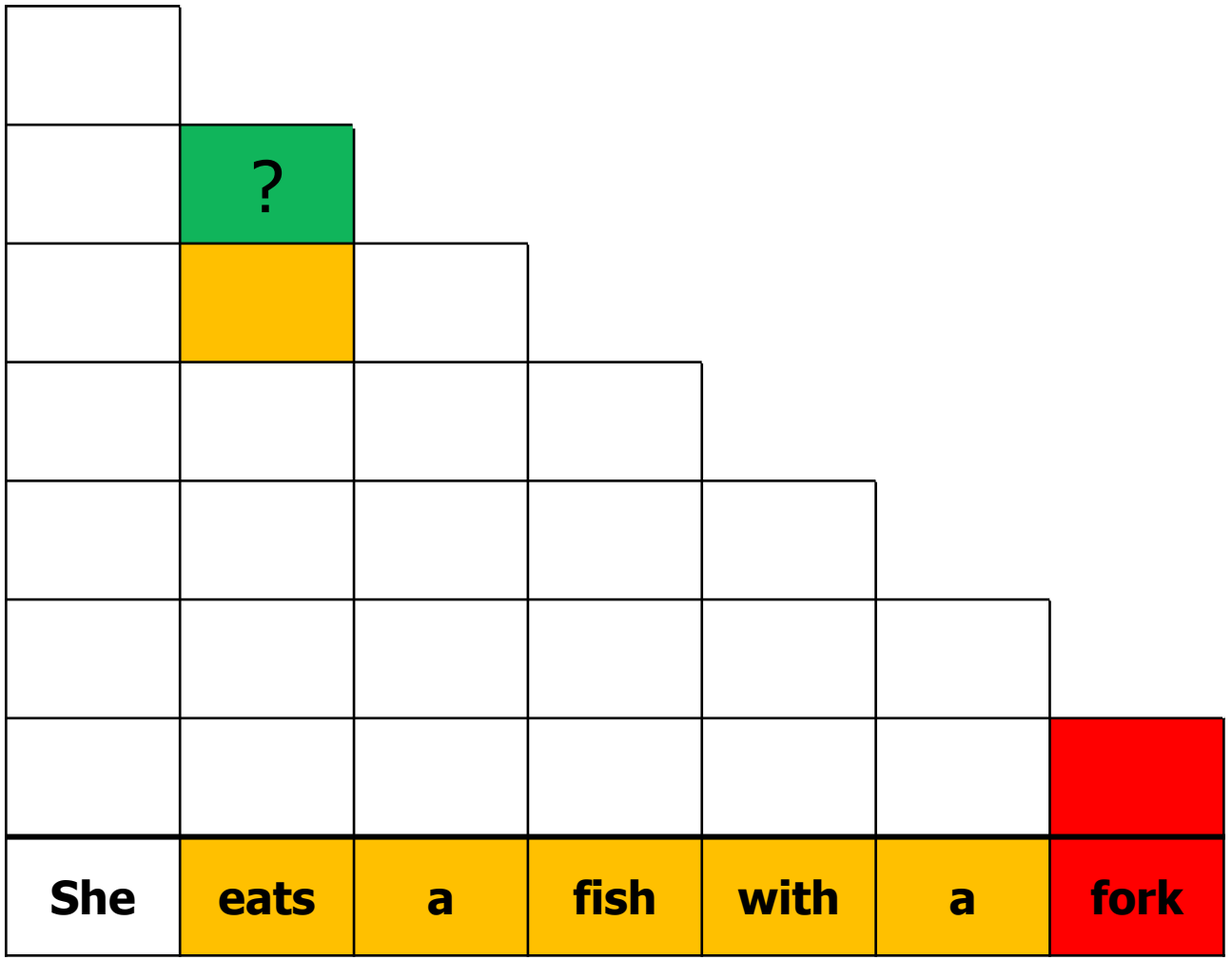
例子：



构成式语法的语法解析算法：CKY

例子：

S						
	VP					
S						
	VP			PP		
S		NP			NP	
NP	V, VP	DET	N	P	DET	N
She	**eats**	**a**	**fish**	**with**	**a**	**fork**

构成式语法的语法解析算法：CKY

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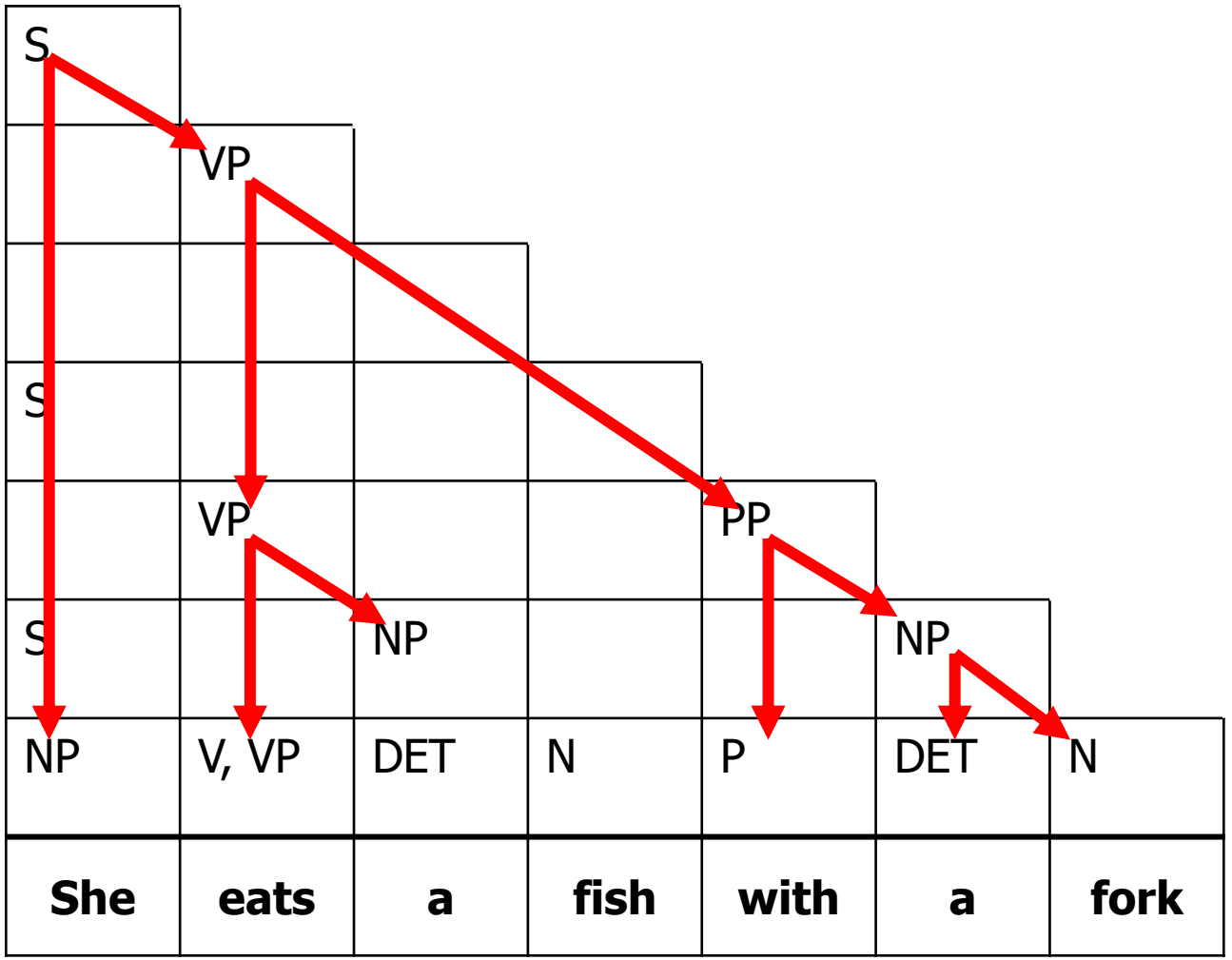

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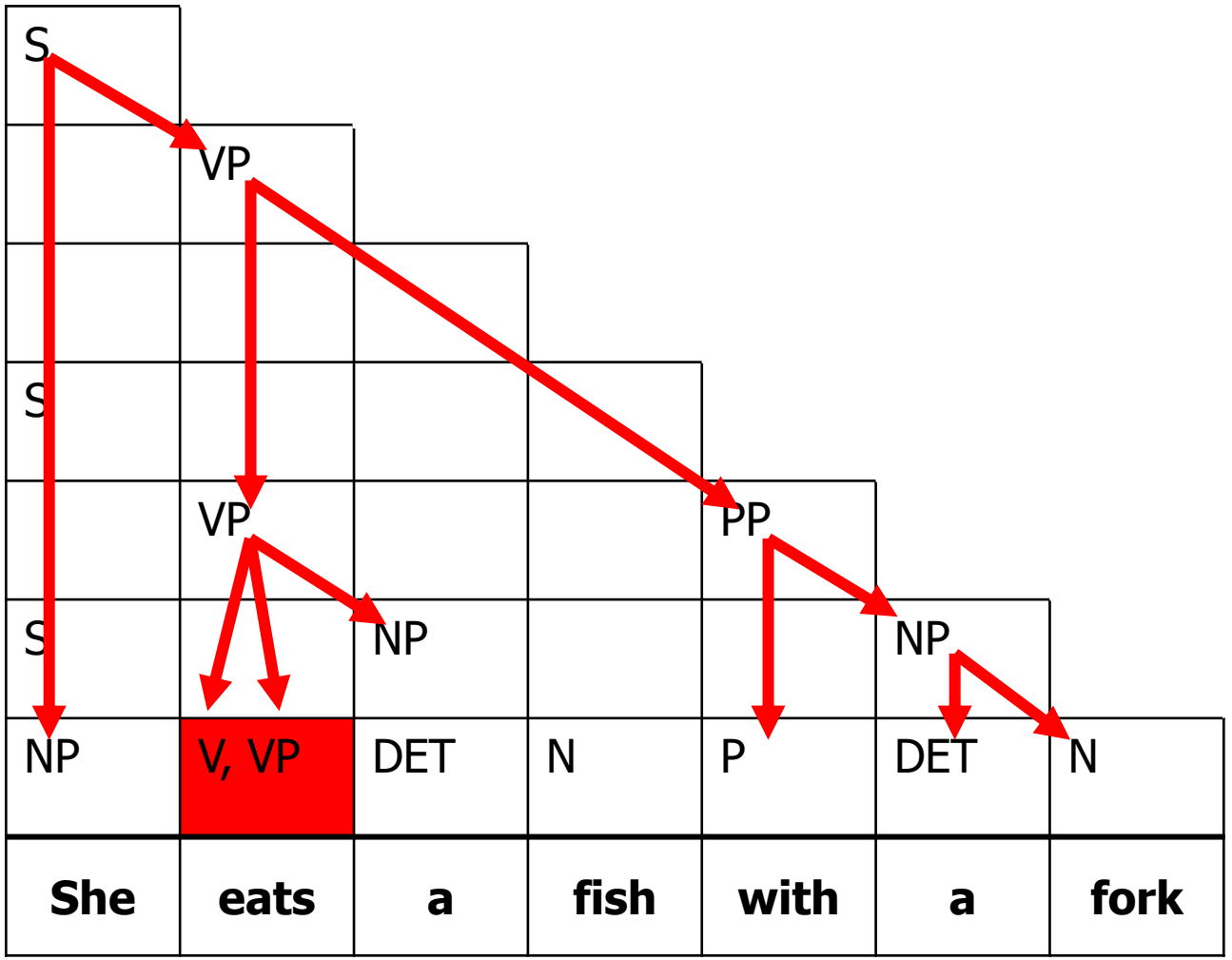


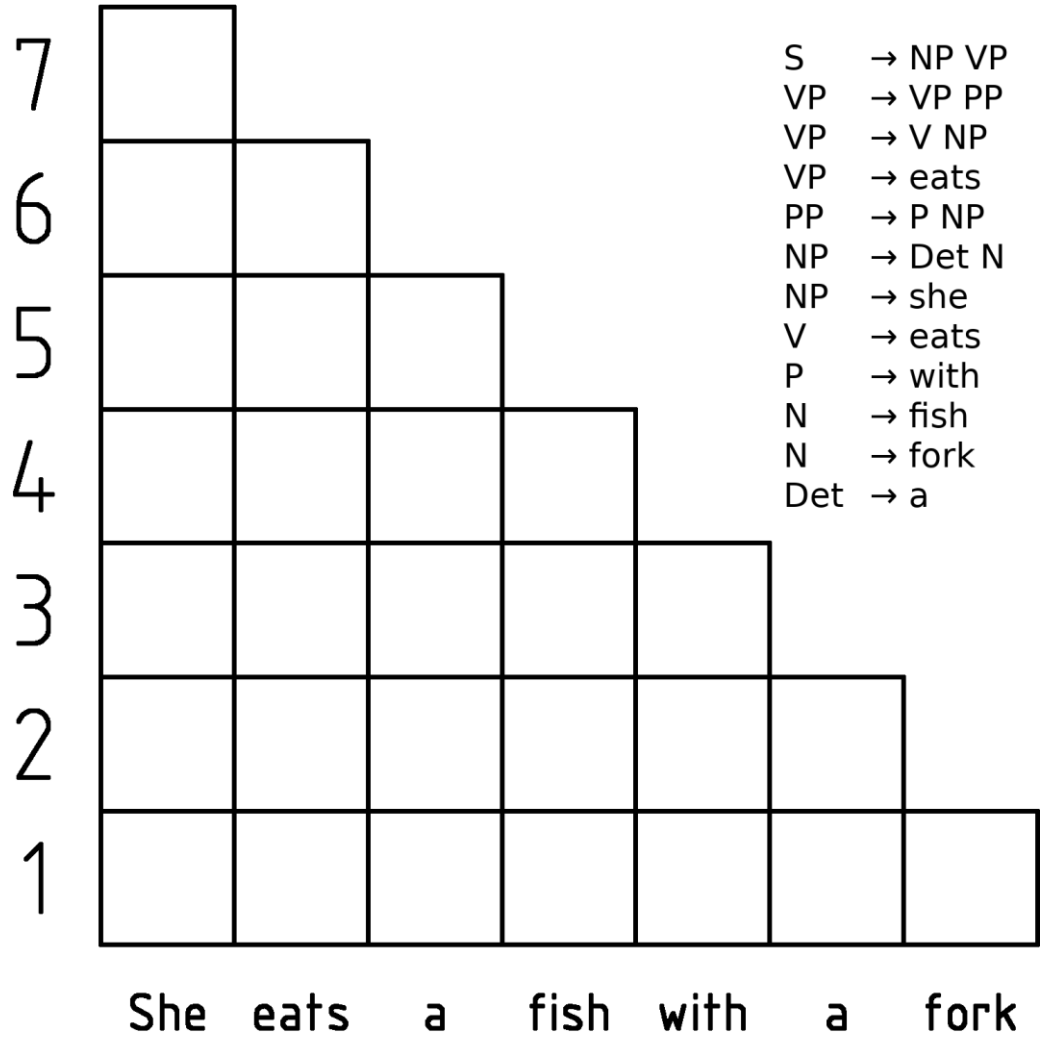
构成式语法的语法解析算法：CKY

CKY算法，全称Cocke–Younger–Kasami算法，由三位计算机科学家于1970年提出。

John Cocke
1987 Turing Award

Tadao Kasami
嵩忠雄

Daniel H. Younger



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将R中规则赋予概率

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CFG与PCFG

概率化的上下文无关语法
（Probablistic CFG，PCFG）

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VP → Verb NP
VP → Verb NP PP

R 语法规则，即$\alpha \rightarrow \beta$形式的规则。α与β均可代表由$N \cup \Sigma$中的元素构成的序列

S → NP VP
NP → Pronoun
NP → Proper-Noun
NP → Det Nominal
Nominal → Nominal Noun
Nominal → Noun
PP → Preposition NP
VP → Verb
VP → Verb NP
VP → Verb NP PP
VP → Verb PP

Noun → flights | breeze | trip | morning
Verb → is | prefer | like | need | want | fly
Adjective → cheapest | non-stop | first | latest | other | direct
Pronoun → me | I | you | it
Proper-Noun → Alaska | Baltimore | Los Angeles | Chicago | United | American
Determiner → the | a | an | this | these | that
Preposition → from | to | on | near
Conjunction → and | or | but

概率化的上下文无关语法（PCFG）

概率化的上下文无关语法
（Probablistic CFG，PCFG）

在CFG要求的基础上：

对每一条生成规则赋予概率p，表示给定规则左边的constituent之后，这个constituent依照该条语法规则生成子树的条件概率。

即对于由A生成的规则：

$$A \longrightarrow \beta \ [p]$$

有

$$p = \mathrm{P}(\beta|A)$$

S → NP VP [1]
NP → Pronoun [0.3]
NP → Proper-Noun [0.3]
NP → Det Nominal [0.4]

PP → Preposition NP [1]
VP → Verb [0.2]
VP → Verb NP [0.2]
VP → Verb NP PP [0.6]

将R中规则赋予概率

上下文无关语法
(Context-free Grammar，CFG)

语法树的生成与上下文无关，即：每一条语法规则中，“→”号左边均为单个的N中元素情况

S → NP VP
NP → Pronoun
NP → Proper-Noun
NP → Det Nominal

PP → Preposition NP
VP → Verb
VP → Verb NP
VP → Verb NP PP

概率化的上下文无关语法（PCFG）

概率化的上下文无关语法
（Probablistic CFG，PCFG）

Rules			P
S	→	VP	.05
VP	→	Verb NP	.20
NP	→	Det Nominal	.20
Nominal	→	Nominal Noun	.20
Nominal	→	Noun	.75
Verb	→	book	.30
Det	→	the	.60
Noun	→	dinner	.10
Noun	→	flight	.40

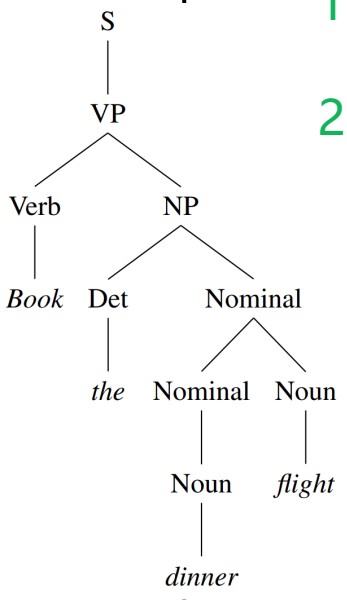
Rules			P
S	→	VP	.05
VP	→	Verb NP NP	.10
NP	→	Det Nominal	.20
NP	→	Nominal	.15
Nominal	→	Noun	.75
Nominal	→	Noun	.75
Verb	→	book	.30
Det	→	the	.60
Noun	→	dinner	.10
Noun	→	flight	.40

1. 判断给定的语法树是否合法。
2. 给定句子，推断出他合法的语法树。
3. 给定句子，在所有合法的语法树中，给出最有可能的语法结构。
4. 像语言模型一样计算给定句子的概率。

上下文无关语法
（Context-free Grammar，CFG）

Rules			Rules		
S	→	VP	S	→	VP
VP	→	Verb NP	VP	→	Verb NP NP
NP	→	Det Nominal	NP	→	Det Nominal
Nominal	→	Nominal Noun	NP	→	Nominal
Nominal	→	Noun	Nominal	→	Noun
			Nominal	→	Noun
Verb	→	book	Verb	→	book
Det	→	the	Det	→	the
Noun	→	dinner	Noun	→	dinner
Noun	→	flight	Noun	→	flight

1. 判断给定的语法树是否合法。
2. 给定句子，推断出他合法的语法树。

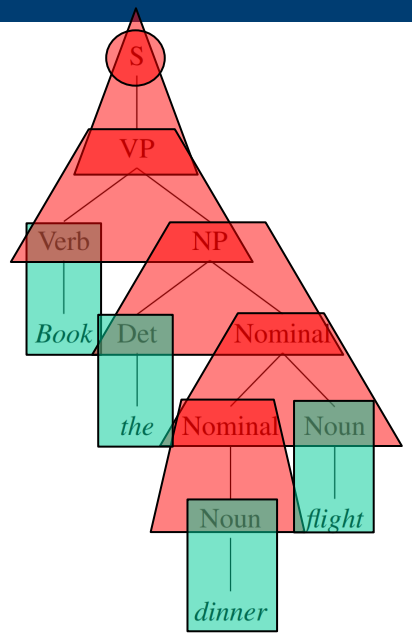


目录

概率化的上下文无关语法（PCFG）

概率化的上下文无关语法
（Probablistic CFG，PCFG）

Rules			P	Rules			P
S	→	VP	.05	S	→	VP	.05
VP	→	Verb NP	.20	VP	→	Verb NP NP	.10
NP	→	Det Nominal	.20	NP	→	Det Nominal	.20
Nominal	→	Nominal Noun	.20	NP	→	Nominal	.15
Nominal	→	Noun	.75	Nominal	→	Noun	.75
				Nominal	→	Noun	.75
Verb	→	book	.30	Verb	→	book	.30
Det	→	the	.60	Det	→	the	.60
Noun	→	dinner	.10	Noun	→	dinner	.10
Noun	→	flight	.40	Noun	→	flight	.40



给定左边语法规则，计算右边句子(V)及其对应的语法树(T)出现的概率。

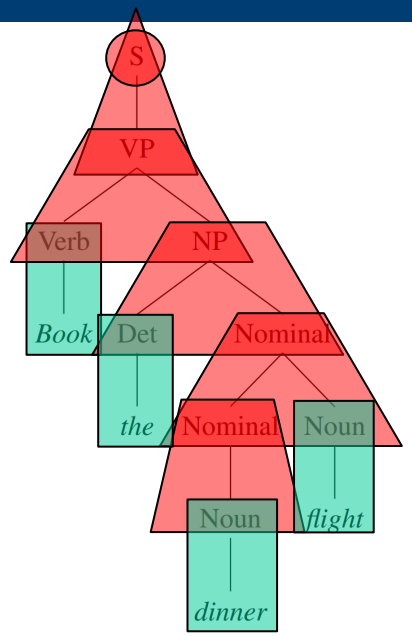
$$P(T,V) = P(S)P(S \to VP|S)P(VP \to Verb\ NP|VP)P(Nominal \to Det\ Nominal|NP)$$
$$P(Nominal \to Nominal\ Noun|Nominal)$$
$$P(Nominal \to Noun|Nominal)$$
$$P(Verb \to Book|Verb)P(Det \to The|Det)P(Noun \to dinner|Noun)$$
$$P(Noun \to flight|Noun)$$

$$P(S) = 1$$

概率化的上下文无关语法（PCFG）

概率化的上下文无关语法
（Probablistic CFG，PCFG）

Rules			P	Rules			P
S	→	VP	.05	S	→	VP	.05
VP	→	Verb NP	.20	VP	→	Verb NP NP	.10
NP	→	Det Nominal	.20	NP	→	Det Nominal	.20
Nominal	→	Nominal Noun	.20	NP	→	Nominal	.15
Nominal	→	Noun	.75	Nominal	→	Noun	.75
				Nominal	→	Noun	.75
Verb	→	book	.30	Verb	→	book	.30
Det	→	the	.60	Det	→	the	.60
Noun	→	dinner	.10	Noun	→	dinner	.10
Noun	→	flight	.40	Noun	→	flight	.40



给定左边语法规则，计算右边句子(V)及其对应的语法树(T)出现的概率。

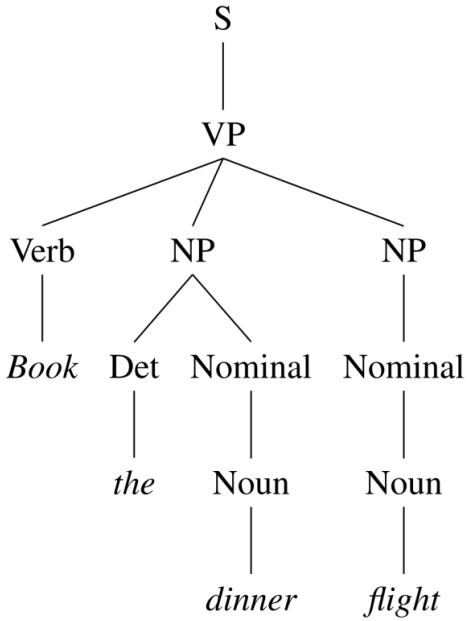
$$P(T,V) = P(S \to VP|S)P(VP \to Verb\ NP|VP)P(Nominal \to Det\ Nominal|NP)$$
$$P(Nominal \to Nominal\ Noun|Nominal)$$
$$P(Nominal \to Noun|Nominal)$$
$$P(Verb \to Book|Verb)P(Det \to The|Det)P(Noun \to dinner|Noun)$$
$$P(Noun \to flight|Noun)$$

$$P(T,V) = 0.05 \times 0.2 \times 0.2 \times 0.2 \times 0.75 \times 0.3 \times 0.6 \times 0.1 \times 0.4 = 2.2 \times 10^{-6}$$

概率化的上下文无关语法（PCFG）

概率化的上下文无关语法
（Probablistic CFG，PCFG）

Rules			P	Rules			P
S	→	VP	.05	S	→	VP	.05
VP	→	Verb NP	.20	VP	→	Verb NP NP	.10
NP	→	Det Nominal	.20	NP	→	Det Nominal	.20
Nominal	→	Nominal Noun	.20	NP	→	Nominal	.15
Nominal	→	Noun	.75	Nominal	→	Noun	.75
				Nominal	→	Noun	.75
Verb	→	book	.30	Verb	→	book	.30
Det	→	the	.60	Det	→	the	.60
Noun	→	dinner	.10	Noun	→	dinner	.10
Noun	→	flight	.40	Noun	→	flight	.40



给定左边语法规则，计算右边句子(V)及其对应的语法树(T)出现的概率。

$$P(T,V) =$$

$$=$$

概率化的上下文无关语法（PCFG）

概率化的上下文无关语法
（Probablistic CFG，PCFG）

Rules			P
S	→	VP	.05
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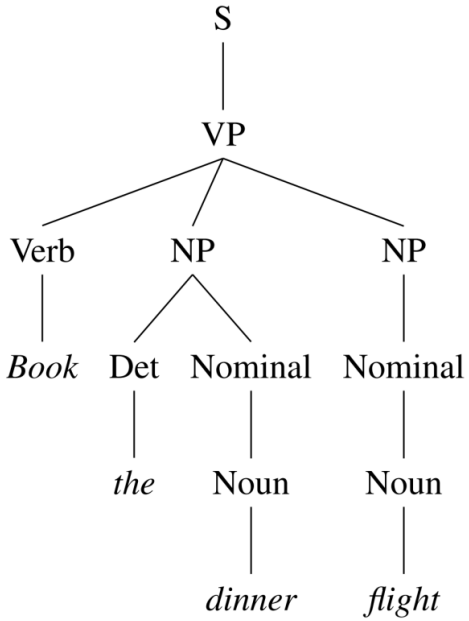


给定一个句子，推断出其概率最大的语法树(T)即是这样一个优化问题：

$$\hat{T}(V) = \underset{T\ s.t.\ y(T)=V}{\operatorname{argmax}} P(T|V)$$

我们可以通过Probablistic CKY算法来求解这个argmax()的结果

目录

PCFG的语法解析：Probablistic CKY

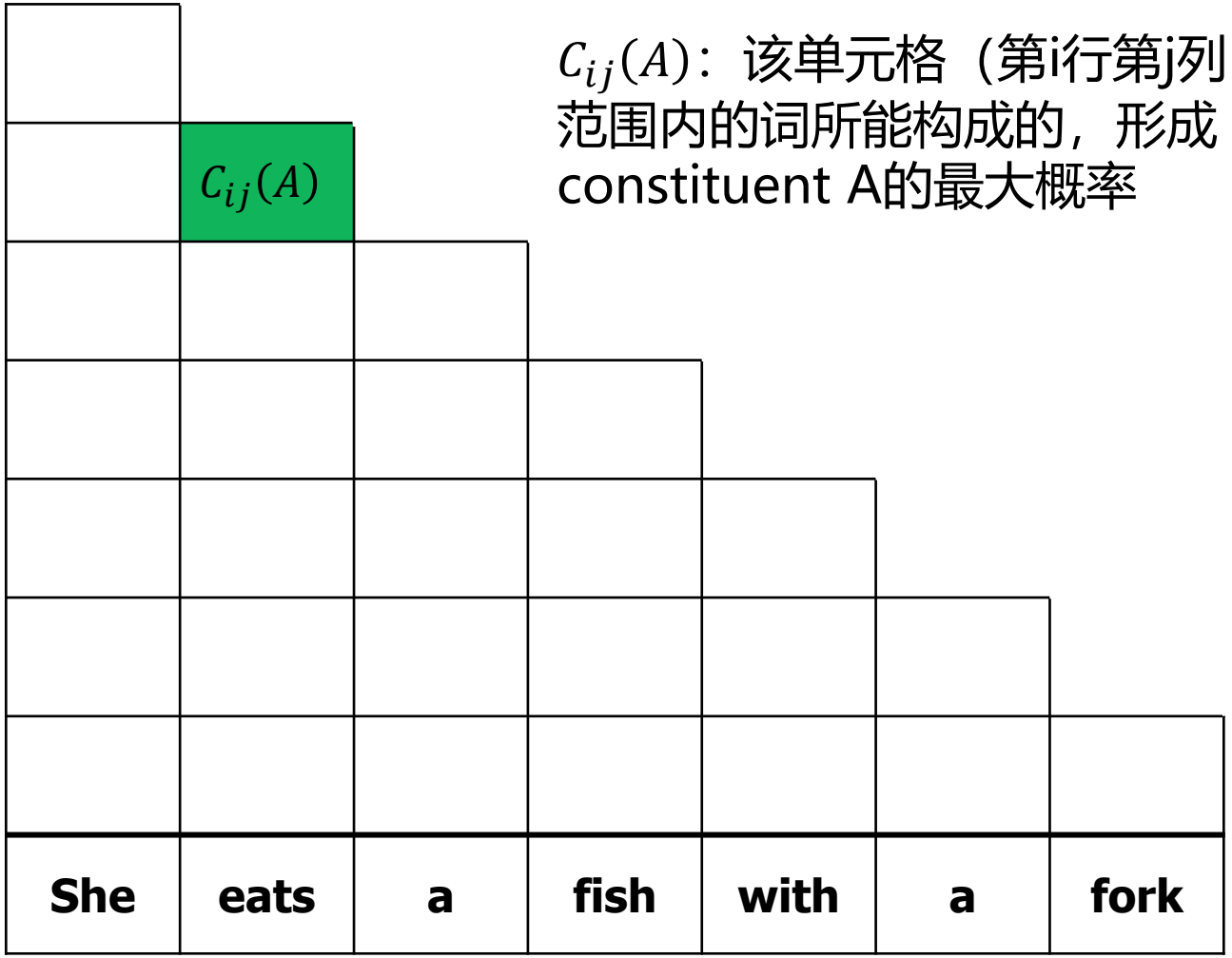
例子：

$$
\begin{aligned}
\mathrm{S} &\longrightarrow \mathrm{NP\ VP} \\
\mathrm{VP} &\longrightarrow \mathrm{VP\ PP} \\
\mathrm{VP} &\longrightarrow \mathrm{V\ NP} \\
\mathrm{PP} &\longrightarrow \mathrm{P\ NP} \\
\mathrm{NP} &\longrightarrow \mathrm{Det\ N}
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{VP} &\longrightarrow \mathrm{eats} \\
\mathrm{NP} &\longrightarrow \mathrm{she} \\
\mathrm{V} &\longrightarrow \mathrm{eats} \\
\mathrm{P} &\longrightarrow \mathrm{with} \\
\mathrm{N} &\longrightarrow \mathrm{fish} \\
\mathrm{N} &\longrightarrow \mathrm{fork} \\
\mathrm{Det} &\longrightarrow \mathrm{a}
\end{aligned}
$$

She eats a fish with a fork

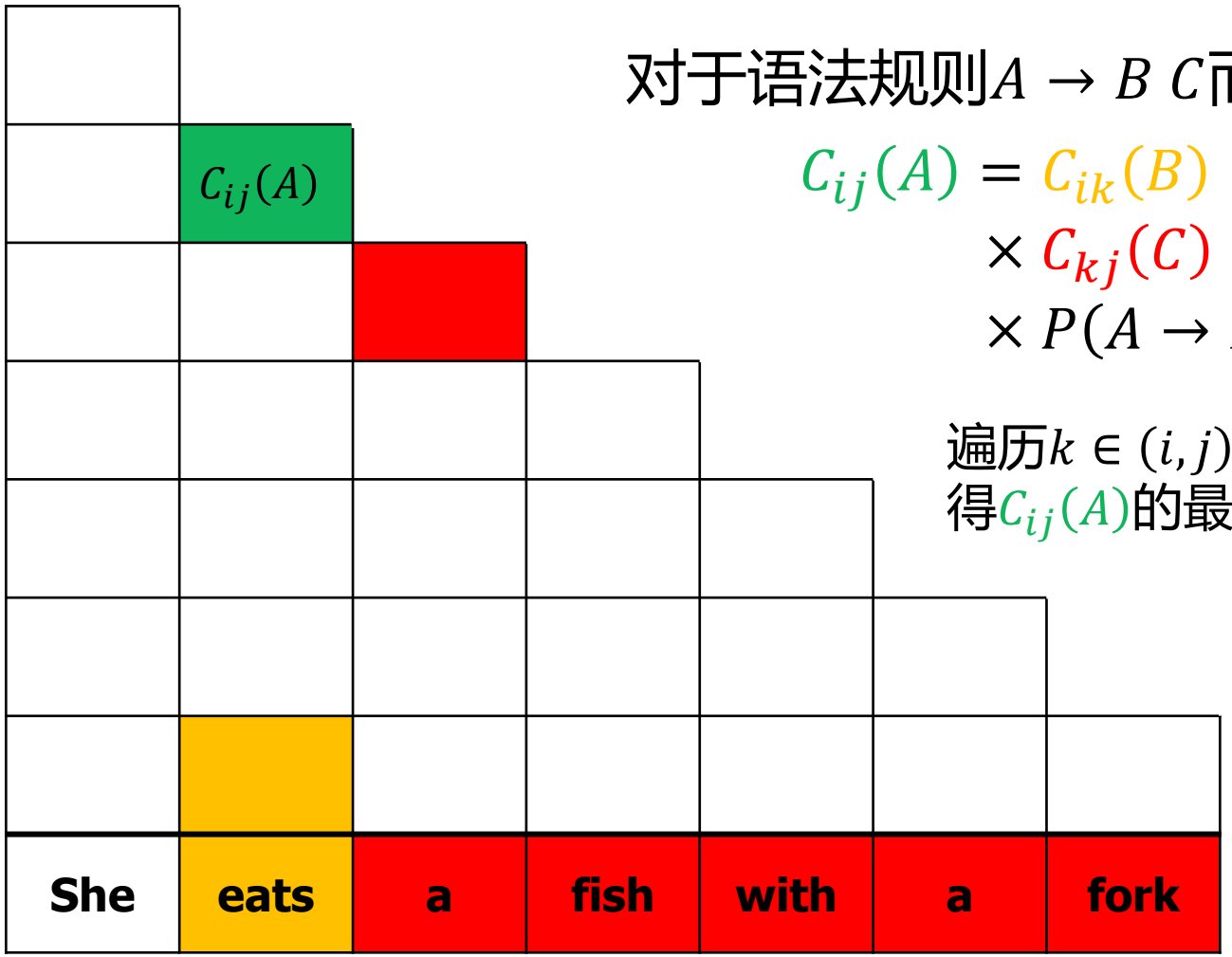
PCFG的语法解析：Probablistic CKY



$C_{ij}(A)$：该单元格（第i行第j列）所对应范围内的词所能构成的，形成constituent A的最大概率

PCFG的语法解析：Probablistic CKY

例子：



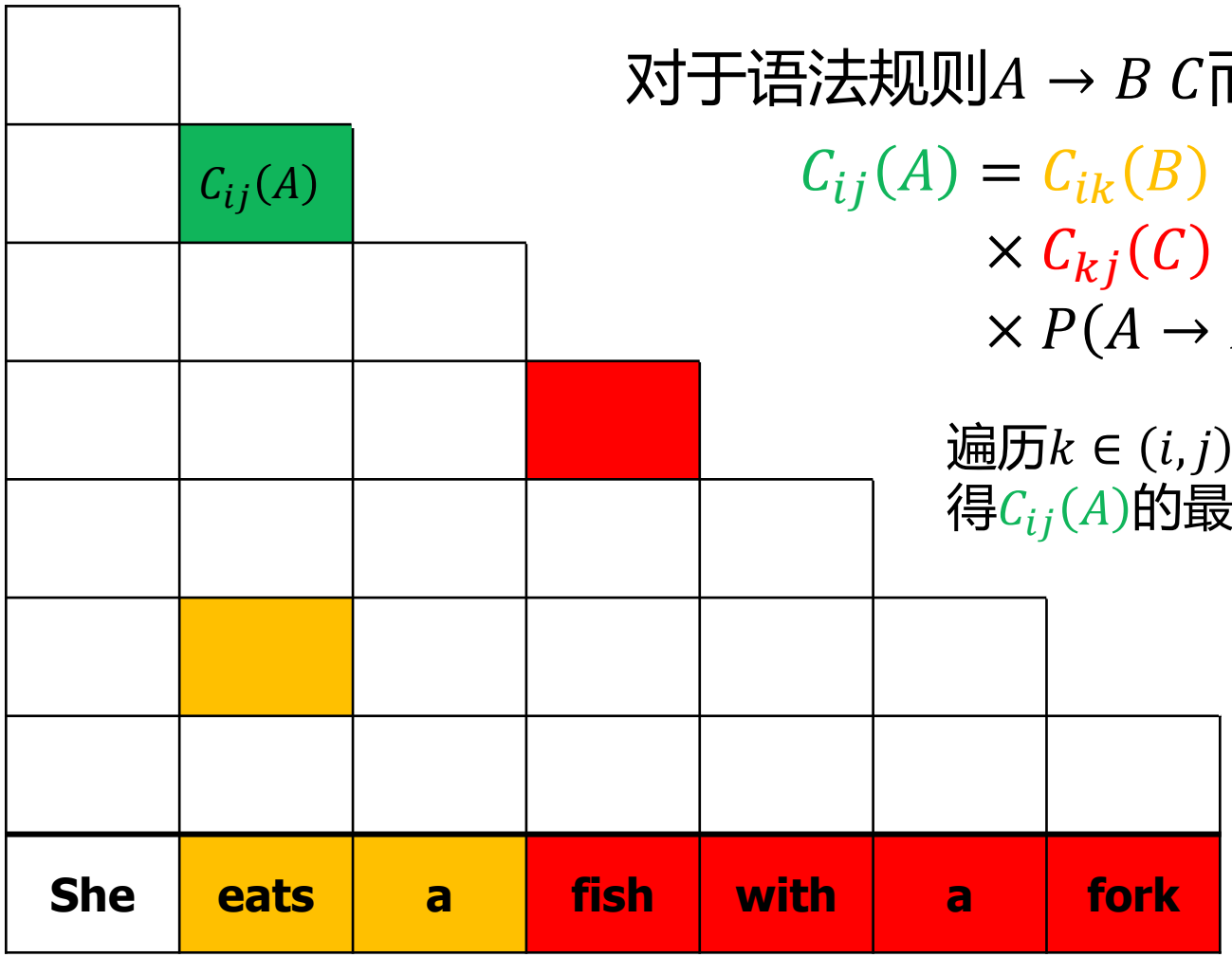
对于语法规则$A \rightarrow B\ C$而言：

$$C_{ij}(A) = C_{ik}(B) \times C_{kj}(C) \times P(A \rightarrow B\ C|A)$$

遍历$k \in (i,j)$即可求得$C_{ij}(A)$的最大值

PCFG的语法解析：Probablistic CKY

例子：



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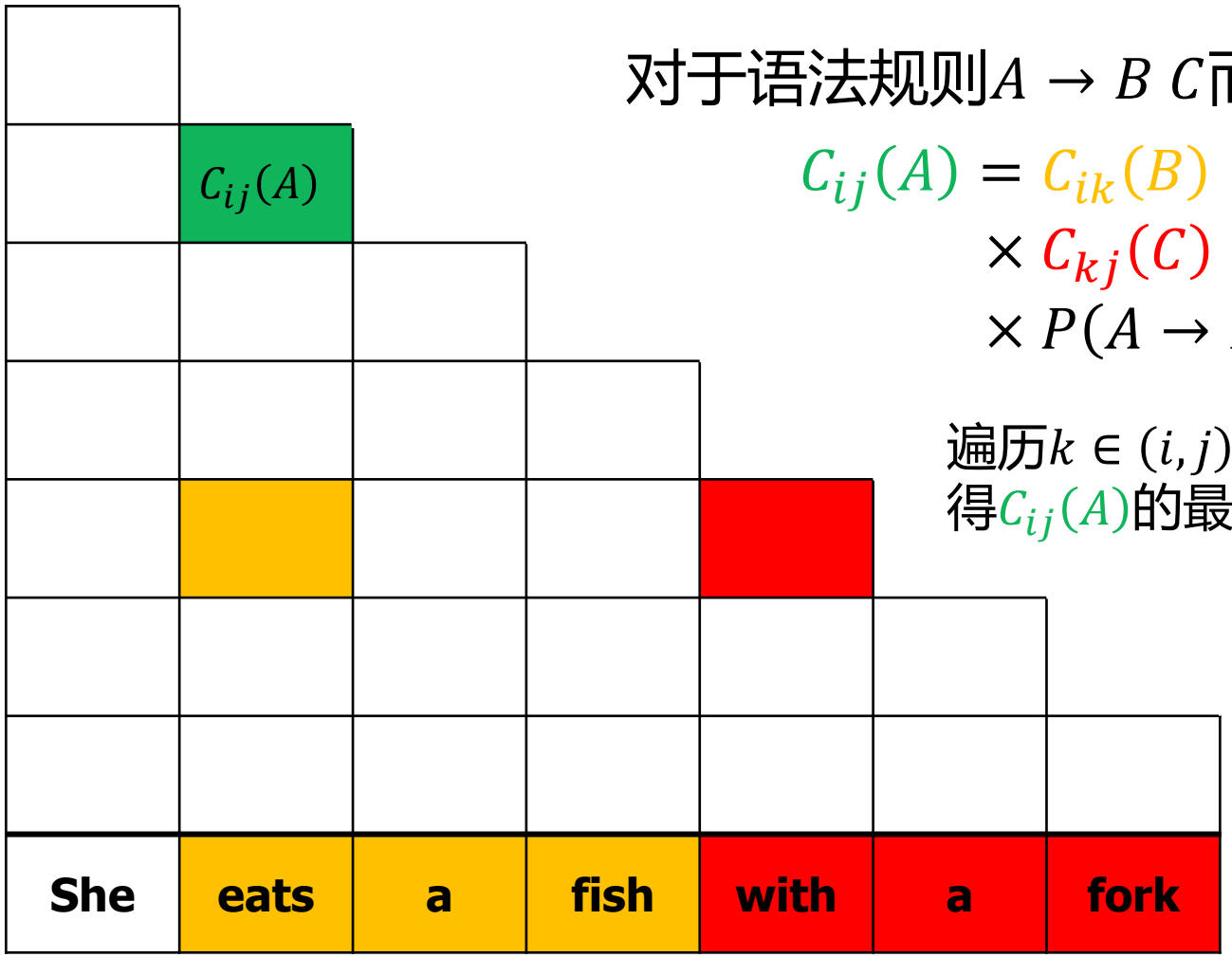
遍历$k \in (i,j)$即可求得$C_{ij}(A)$的最大值

PCFG的语法解析：Probablistic CKY

例子：



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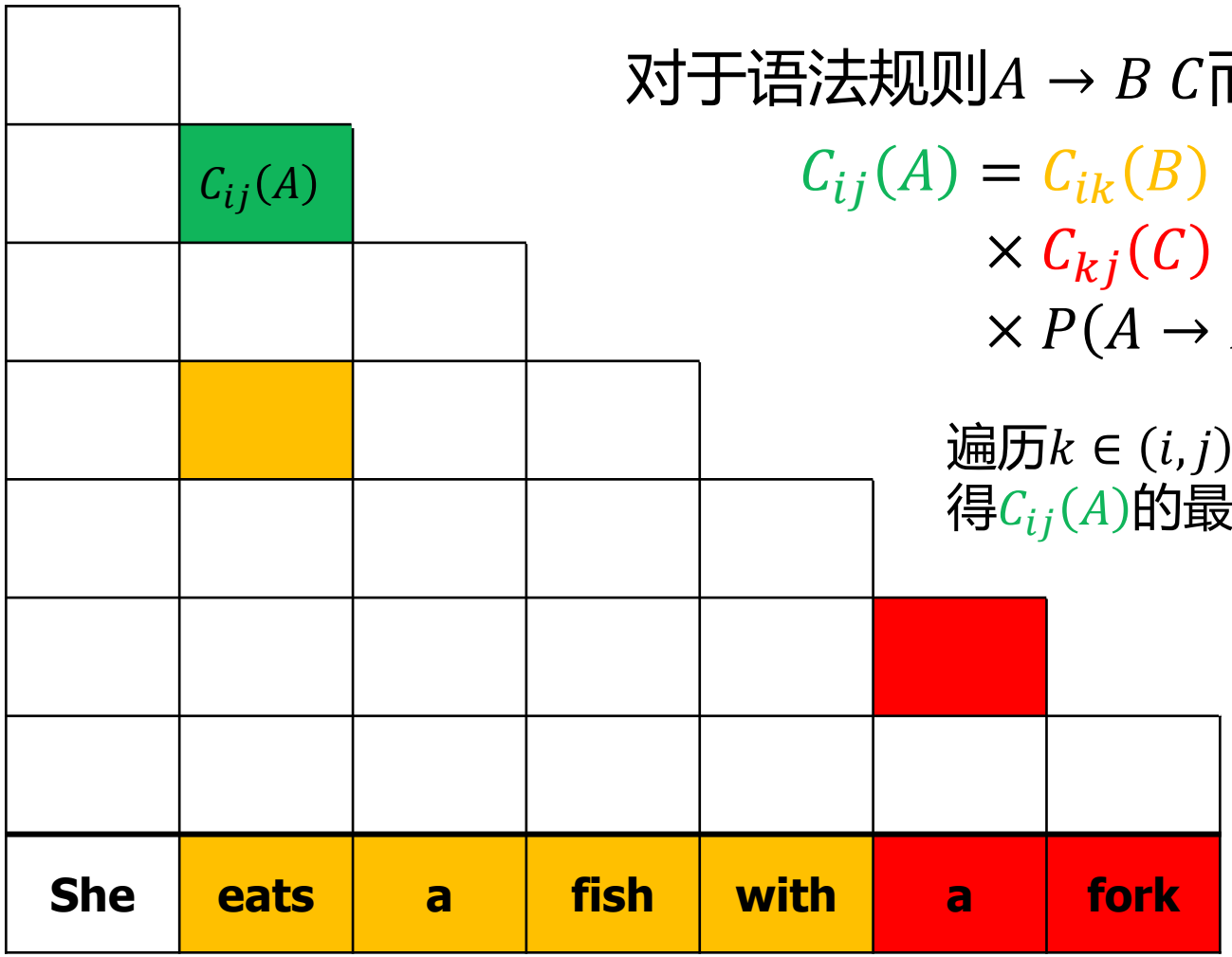
PCFG的语法解析：Probablistic CKY

例子：



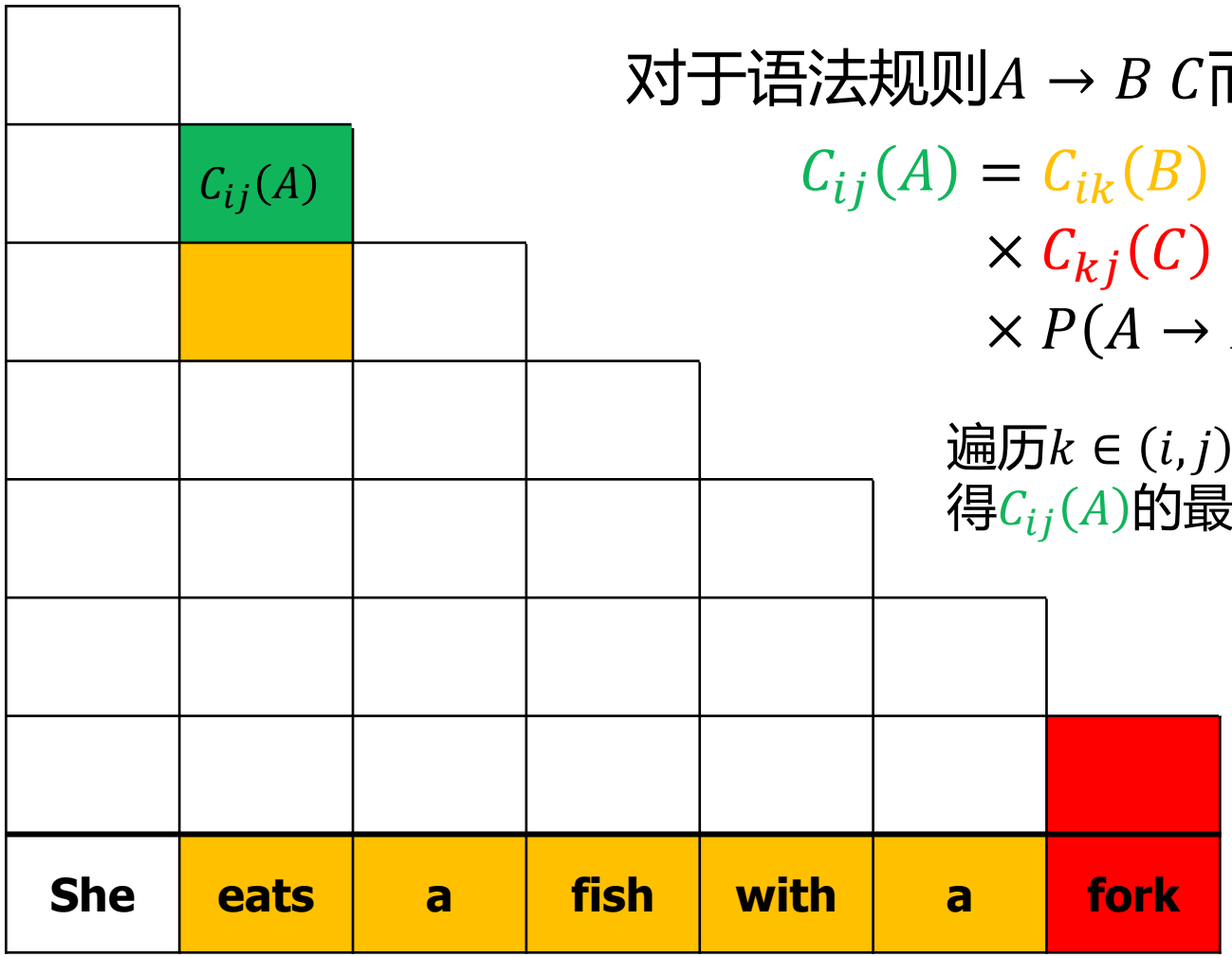
对于语法规则$A \rightarrow B\ C$而言：

$$C_{ij}(A) = C_{ik}(B) \times C_{kj}(C) \times P(A \rightarrow B\ C|A)$$

遍历$k \in (i,j)$即可求得$C_{ij}(A)$的最大值

PCFG的语法解析：Probablistic CKY

例子：



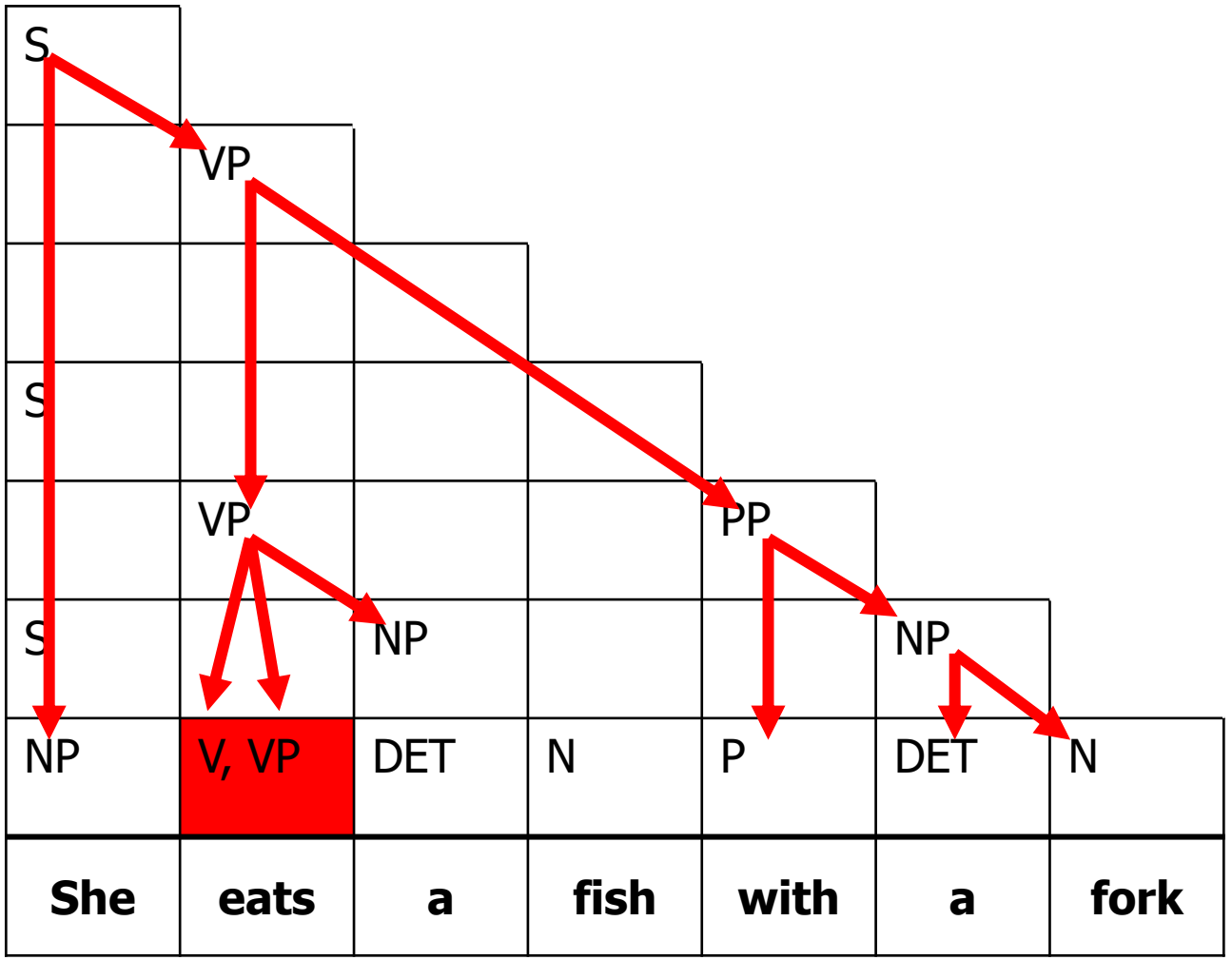
对于语法规则$A \rightarrow B\ C$而言：

$$C_{ij}(A) = C_{ik}(B) \times C_{kj}(C) \times P(A \rightarrow B\ C|A)$$

遍历$k \in (i,j)$即可求得$C_{ij}(A)$的最大值

构成式语法的语法解析算法：CKY

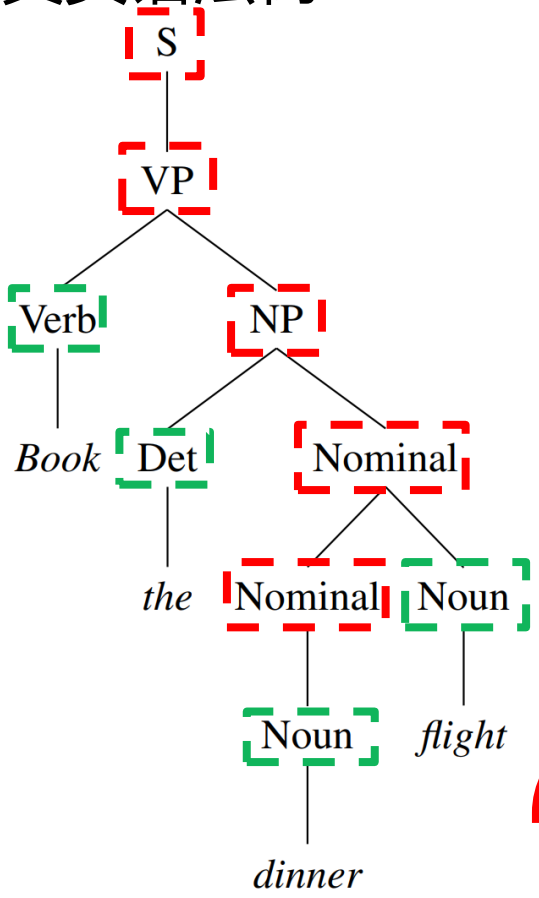
例子：



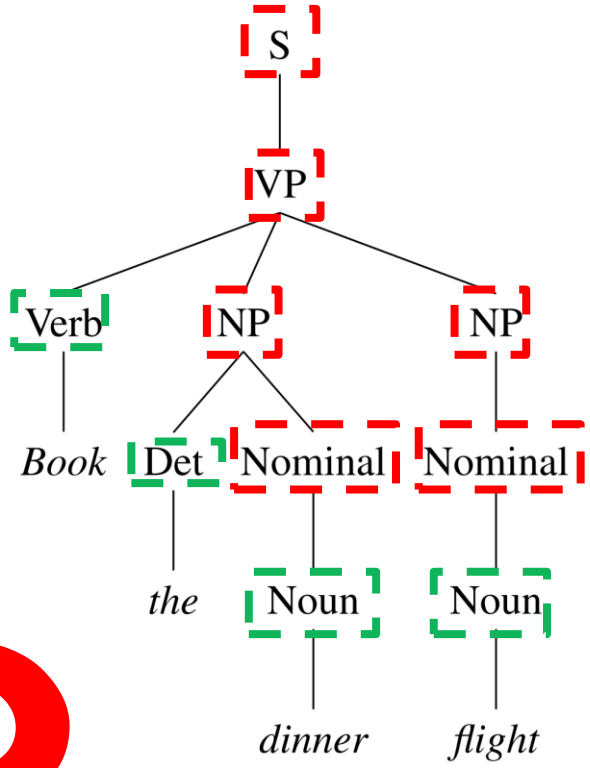
目录

评价指标

真实语法树

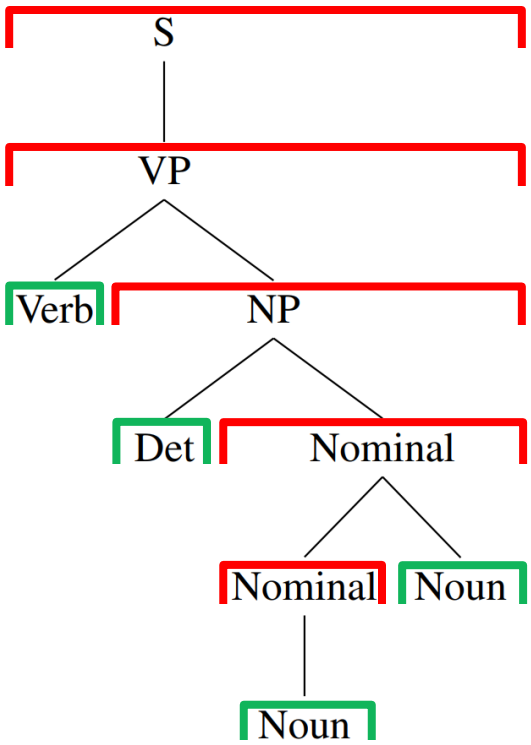


模型预测的语法树



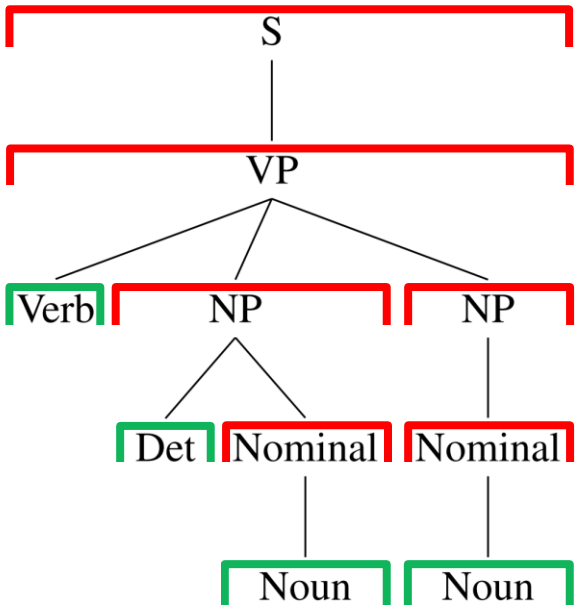
评价指标

真实语法树



Book the dinner flight

模型预测的语法树



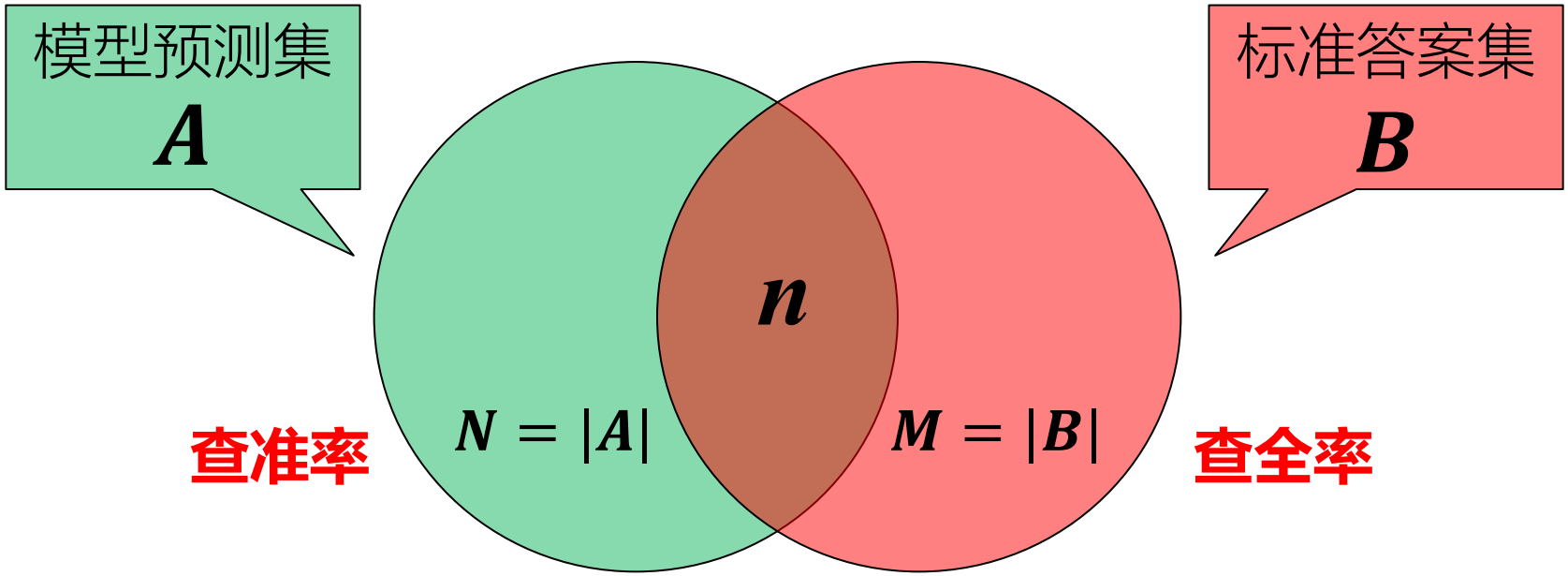
Book the dinner flight

考虑每一个constituent的涵盖范围。对于某个constituent而言，若能在另一棵语法树中找到一个涵盖范围与标签均相同的constituent，则视为一个匹配；否则视为不匹配。

→ ∀CNF，若两棵树中若所有的constituent都匹配，则必然语法树完全相同。

中文分词的评价指标：F-measure

假设系统输出N个结果，其中，正确的结果为n个，标准答案的个数为M个



$$F_1 = \frac{2PR}{P+R} \times 100\%$$

$$P = \frac{n}{N} \times 100\%$$

$$R = \frac{n}{M} \times 100\%$$

评价指标

使用 {模型的预测的constituents的集合} 与 {真实语法树中的constituents} 两个集合的重合程度，即F_1分数，来量化评价语法解析的质量。

- Labeled F_1：考虑constituents涵盖范围以及标签。仅当两方面都正确时，才视作匹配
- Unlabeled F_1：只考虑constituents涵盖范围，即便标签预测错误，也视作是匹配

目录

常用工具

在线语法解析demo：

https://parser.kitaev.io/（Berkeley Neural Parser）
https://www.link.cs.cmu.edu/link/submit-sentence-4.html
https://corenlp.run/（Stanford Parser）

语法解析评价指标的标准实现：

Evalb (https://nlp.cs.nyu.edu/evalb/)

repo和模型：

Model	F1 score	Paper / Source
Label Attention Layer + HPSG + XLNet (Mrini et al., 2020)	96.38	Rethinking Self-Attention: Towards Interpretability for Neural Parsing
Attach-Juxtapose Parser + XLNet (Yang and Deng, 2020)	96.34	Strongly Incremental Constituency Parsing with Graph Neural Networks
Head-Driven Phrase Structure Grammar Parsing (Joint) + XLNet (Zhou and Zhao, 2019)	96.33	Head-Driven Phrase Structure Grammar Parsing on Penn Treebank
Head-Driven Phrase Structure Grammar Parsing (Joint) + BERT (Zhou and Zhao, 2019)	95.84	Head-Driven Phrase Structure Grammar Parsing on Penn Treebank
CRF Parser + BERT (Zhang et al., 2020)	95.69	Fast and Accurate Neural CRF Constituency Parsing