Computational Linguistics II

— Grammars, Algorithms, Statistics —

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Candidate Theories of Grammar (1 of 3)

Language as a Set of Strings

The dog barks.
The angry dog barks.
The fierce dog barks.
The fierce angry dog barks.
The angry fierce dog barks.
The dog chased a cat.
A dog chased the cat.
The dog chased a black cat.
The dog chased a young cat.
The dog of my neighbours chased a cat.
A dog chased the cat of my neighbours.
The cat of my neighbours was chased by a dog.
...

Candidate Theories of Grammar (2 of 3)

Language as a Sequence of Words

a, *the*, *my*, *that*, ...	**determiner (D)**
cat, *dog*, *neighbours*, ...	**noun (N)**
fierce, *angry*, *black*, *young*, ...	**adjective (A)**
barks, *chased*, *was*, ...	**verb (V)**
of, *by*, *on*, *at*, *under*, ...	**preposition (P)**

Regular Expressions

$$X^+ \equiv \{ X \mid XX \mid XXX \mid XXXX \mid \ldots \}$$
$$X^* \equiv \{ \_ \mid X \mid XX \mid XXX \mid XXXX \mid \ldots \}$$

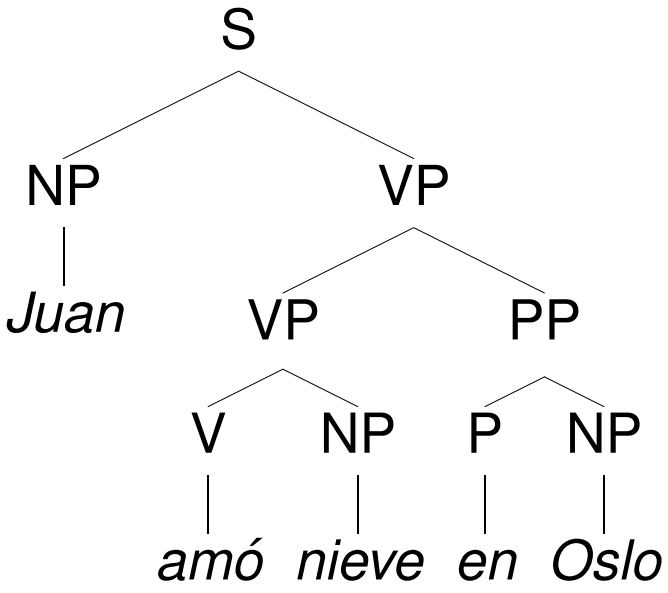
The English Noun Phrase

$$\mathrm{D\ A^*\ N^+} \left(\mathrm{P\ D\ A^*\ N^+} \right)^?$$

Phrase Structure Grammars (By Example)

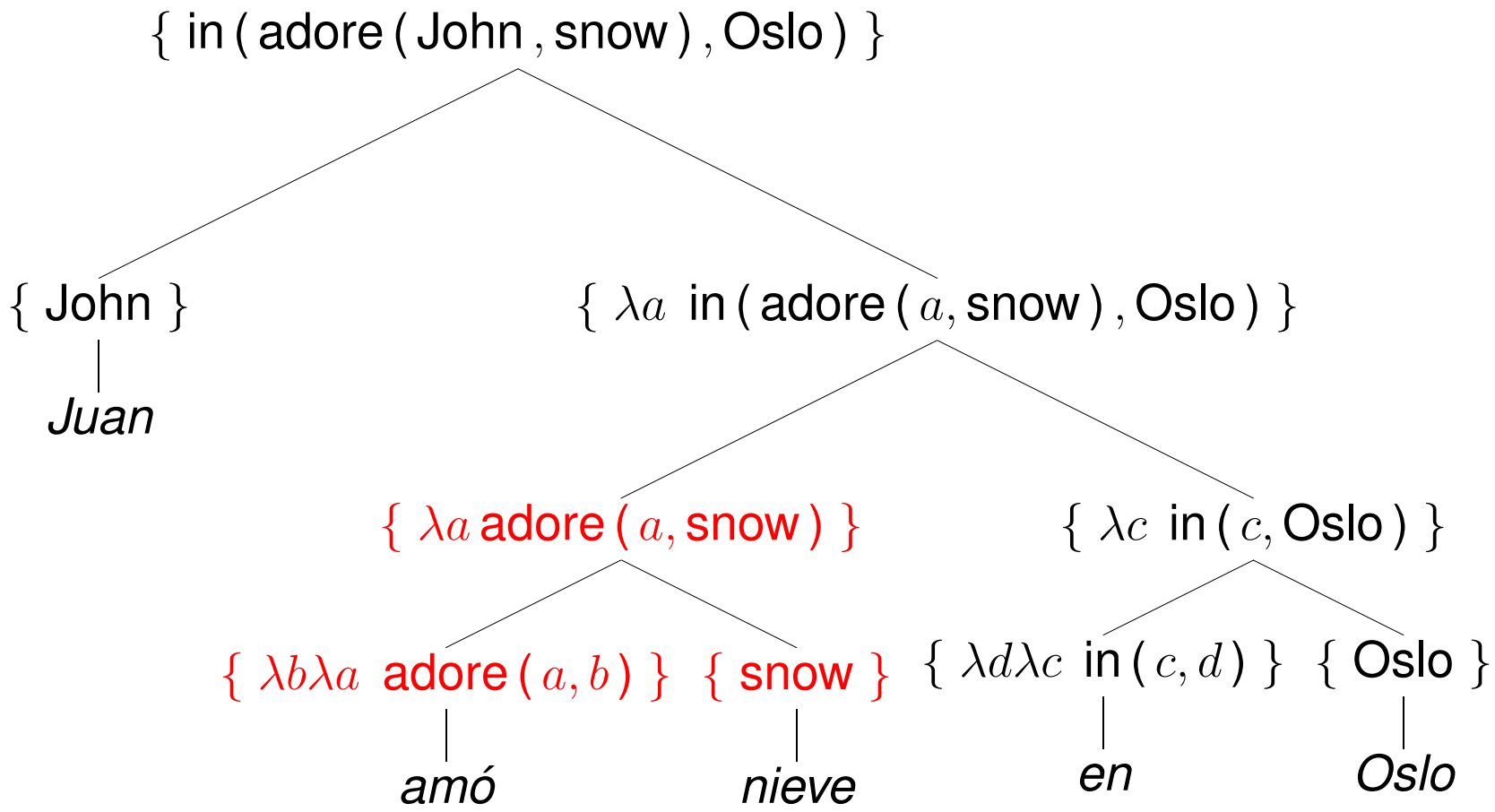
The Grammar of Spanish

S → NP VP	{ VP (NP) }
VP → V NP	{ V (NP) }
VP → VP PP	{ PP (VP) }
PP → P NP	{ P (NP) }
NP → “nieve”	{ snow }
NP → “Juan”	{ John }
NP → “Oslo”	{ Oslo }
V → “amó”	{ $\lambda b \lambda a$ adore (a, b) }
P → “en”	{ $\lambda d \lambda c$ in (c, d) }



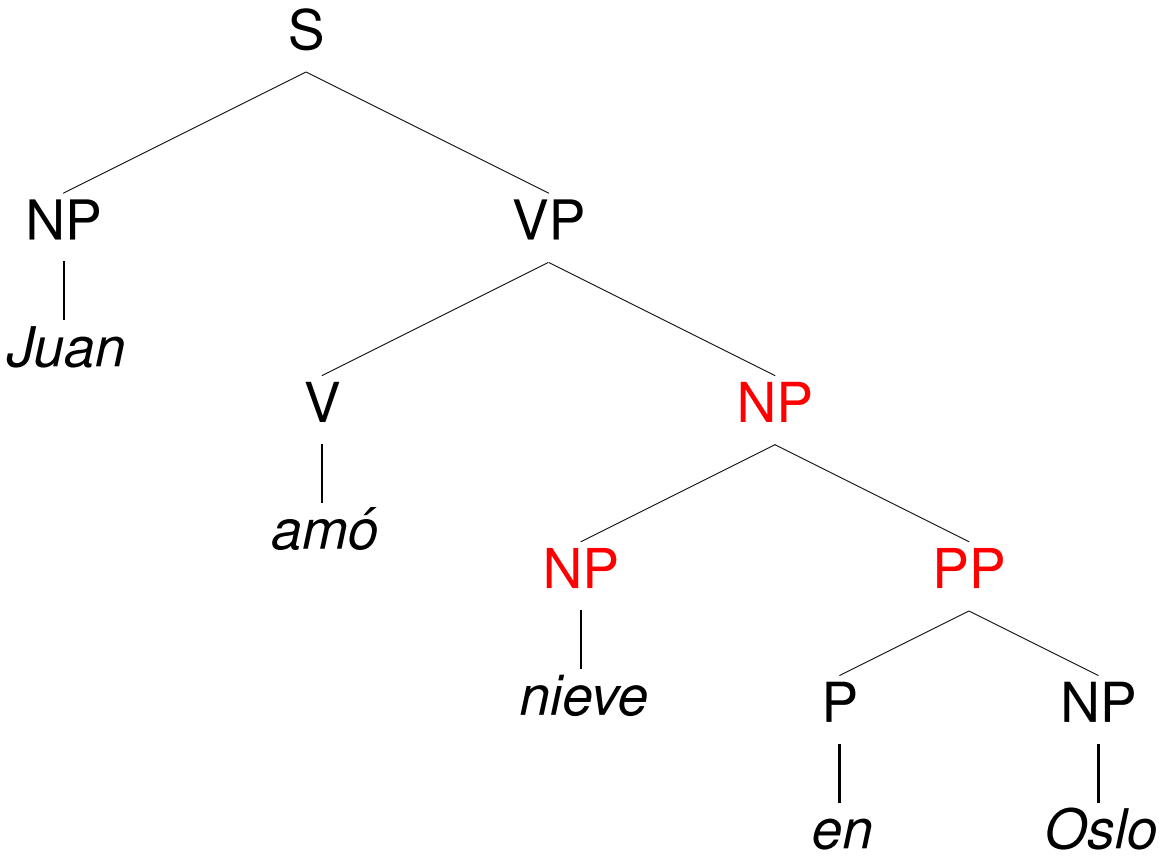
Juan amó nieve en Oslo

Meaning Composition (Grossly Simplified, Still)



VP → V NP { V (NP) }

Another Interpretation — Structural Ambiguity



NP → NP PP { PP (NP) }

Reminding Ourselves — Context-Free Grammars

- Formally, a *context-free grammar* (CFG) is a quadruple: $\langle C, \Sigma, P, S \rangle$
- C is the set of categories (aka *non-terminals*), e.g. $\{\text{S}, \text{NP}, \text{VP}, \text{V}\}$;
- Σ is the vocabulary (aka *terminals*), e.g. $\{\text{Juan}, \text{nieve}, \text{amó}\}$;
- P is a set of category rewrite rules (aka *productions*), e.g.

$$\begin{aligned} \text{S} &\rightarrow \text{NP VP} \\ \text{VP} &\rightarrow \text{V NP} \\ \text{NP} &\rightarrow \text{Juan} \\ \text{NP} &\rightarrow \text{nieve} \\ \text{V} &\rightarrow \text{amó} \end{aligned}$$

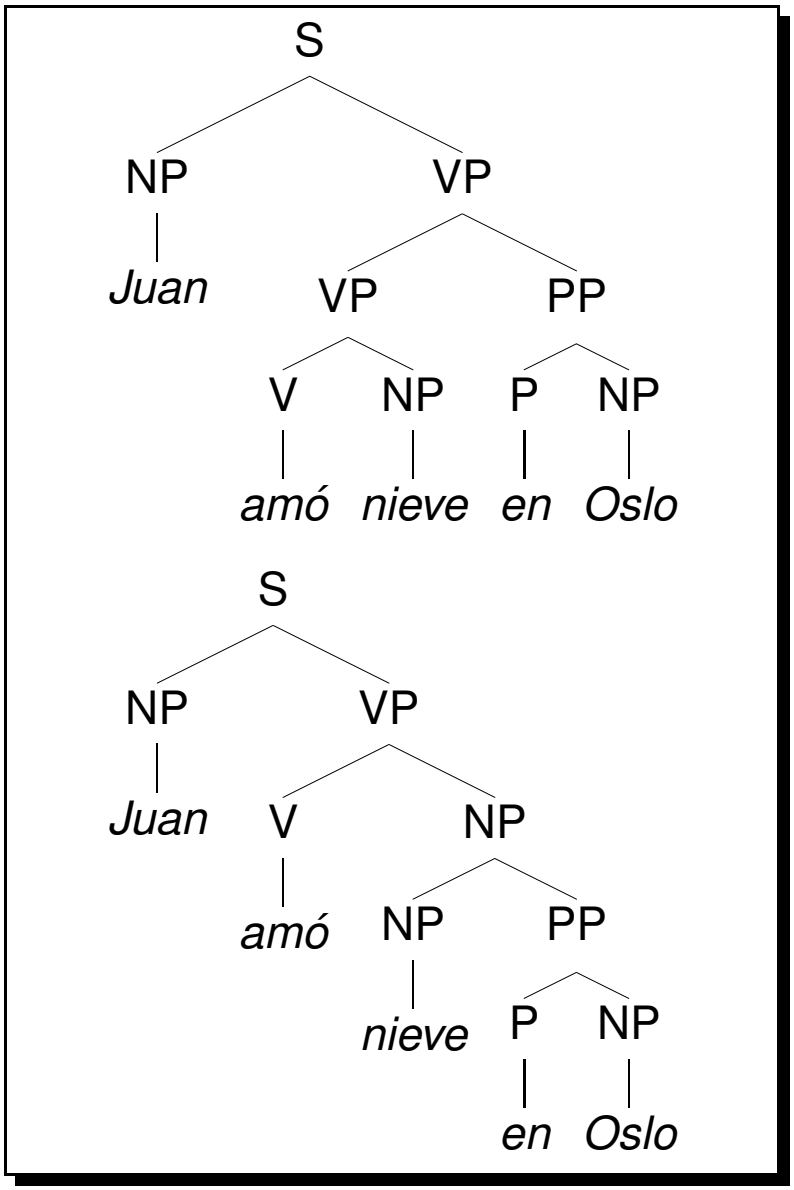
- $S \in C$ is the *start symbol*, a filter on complete ('sentential') results;
- for each rule '$\alpha \rightarrow \beta_1, \beta_2, ..., \beta_n$' $\in P$: $\alpha \in C$ and $\beta_i \in C \cup \Sigma$; $1 \leq i \leq n$.

Parsing: Recognizing the Language of a Grammar

S → NP VP
VP → V NP
VP → VP PP
NP → NP PP
PP → P NP
NP → Juan | nieve | Oslo
V → amó
P → en

All Complete Derivations

- are rooted in the start symbol S;
- label internal nodes with categories $\in C$, leafs with words $\in \Sigma$;
- instantiate a grammar rule $\in P$ at each local subtree of depth one.



Limitations of Context-Free Grammar

Agreement and Valency (For Example)

That dog barks.

**That dogs barks.*

**Those dogs barks.*

The dog chased a cat.

**The dog barked a cat.*

**The dog chased.*

**The dog chased a cat my neighbours.*

The cat was chased by a dog.

**The cat was chased of a dog.*

...

Structured Categories in a Unification Grammar

- All (constituent) categories in the grammar are typed feature structures;
- specific TFS configurations may correspond to ‘traditional’ categories;
- labels like ‘S’ or ‘NP’ are mere abbreviations, not elements of the theory.

$$\textit{word}\begin{bmatrix}\texttt{HEAD} & \textit{noun}\\ \texttt{SPR} & \langle [\,] \rangle \\ \texttt{COMPS} & \langle\rangle\end{bmatrix}$$

‘N’

‘lexical’

$$\textit{phrase}\begin{bmatrix}\texttt{HEAD} & \textit{verb}\\ \texttt{SPR} & \langle\rangle \\ \texttt{COMPS} & \langle\rangle\end{bmatrix}$$

‘S’

‘maximal’

$$\textit{phrase}\begin{bmatrix}\texttt{HEAD} & \textit{verb}\\ \texttt{SPR} & \langle [\,] \rangle \\ \texttt{COMPS} & \langle\rangle\end{bmatrix}$$

‘VP’

‘intermediate’

Interaction of Lexicon and Phrase Structure Schemata

$$\textit{phrase}\begin{bmatrix}\texttt{HEAD} & \boxed{1}\\ \texttt{SPR} & \langle\rangle\\ \texttt{COMPS} & \boxed{3}\end{bmatrix} \longrightarrow \boxed{2}\textit{phrase}\begin{bmatrix}\texttt{SPR} & \langle\rangle\\ \texttt{COMPS} & \langle\rangle\end{bmatrix}, \quad \textit{phrase}\begin{bmatrix}\texttt{HEAD} & \boxed{1}\\ \texttt{SPR} & \langle\boxed{2}\rangle\\ \texttt{COMPS} & \boxed{3}\end{bmatrix}$$

$$\begin{bmatrix}\texttt{PHON} & \langle \textit{Kim}\rangle\\ \texttt{HEAD} & \textit{noun}\begin{bmatrix}\texttt{AGR} & \textit{3sg}\end{bmatrix}\\ \texttt{SPR} & \langle\rangle\\ \texttt{COMPS} & \langle\rangle\end{bmatrix}$$

$$\begin{bmatrix}\texttt{PHON} & \langle \textit{sleeps}\rangle\\ \texttt{HEAD} & \textit{verb}\begin{bmatrix}\texttt{AGR} & \boxed{1}\,\textit{3sg}\end{bmatrix}\\ \texttt{SPR} & \left\langle\begin{bmatrix}\texttt{HEAD} & \textit{noun}\begin{bmatrix}\texttt{AGR} & \boxed{1}\\ \texttt{CASE} & \textit{nom}\end{bmatrix}\\ \texttt{SPR} & \langle\rangle\\ \texttt{COMPS} & \langle\rangle\end{bmatrix}\right\rangle\\ \texttt{COMPS} & \langle\rangle\end{bmatrix}$$

The Format of Grammar Rules in the LKB

$$\textit{phrase}\begin{bmatrix}\texttt{HEAD} & \boxed{1} \\ \texttt{SPR} & \langle\rangle \\ \texttt{COMPS} & \boxed{3}\end{bmatrix} \longrightarrow \boxed{2}\textit{phrase}\begin{bmatrix}\texttt{SPR} & \langle\rangle \\ \texttt{COMPS} & \langle\rangle\end{bmatrix}, \textit{phrase}\begin{bmatrix}\texttt{HEAD} & \boxed{1} \\ \texttt{SPR} & \langle\boxed{2}\rangle \\ \texttt{COMPS} & \boxed{3}\end{bmatrix}$$

$$\textit{phrase}\left[\begin{array}{ll}\texttt{HEAD} & \boxed{1} \\ \texttt{SPR} & \langle\rangle \\ \texttt{COMPS} & \boxed{3} \\ \\ \texttt{ARGS} & \left\langle \boxed{2}\textit{phrase}\left[\begin{array}{ll}\texttt{SPR} & \langle\rangle \\ \texttt{COMPS} & \langle\rangle\end{array}\right], \textit{phrase}\left[\begin{array}{ll}\texttt{HEAD} & \boxed{1} \\ \texttt{SPR} & \langle\boxed{2}\rangle \\ \texttt{COMPS} & \boxed{3}\end{array}\right]\right\rangle\end{array}\right]$$