LING3701/PSYCH3371: Lecture Notes 9
Syntactic Grammars for Human Languages

Contents

9.1 We can use rules to model human languages like English

Human languages have rich category types, that can be seen in conjunctions [Sag et al., 1985].

First, observe that natural languages use different argument structures for different verbs:

- They sleep. – one argument ahead (intransitive)
- They find pets. – one argument ahead and one argument behind (transitive)
- They give people pets. – one argument ahead, two arguments behind (ditransitive)

Next, observe natural languages *coordinate* conjunctions (combine like types): $\langle\alpha\rangle \rightarrow \langle\alpha\rangle$ and $\langle\alpha\rangle$.

- $[_\beta$ $[_\beta$ They sleep] and $[_\beta$ they find pets]]. – sounds ok (β is sentence)
- They find $[_\gamma$ $[_\gamma$ people] and $[_\gamma$ pets]]. – sounds ok (γ is noun phrase)
- *They find $[_\gamma$ $[_\beta$ they sleep] and $[_\gamma$ pets]]. – sounds wrong; conjuncts must match

Now, allowable conjunctions give us insight into the category structure of language:

- They $[_\delta$ $[_\delta$ sleep] and $[_\delta$ find pets]]. – sounds ok (δ is verb phrase)
- They $[_\eta$ $[_\eta$ find] and $[_\eta$ give people]] pets. – sounds ok (but what's η?)

Transitive verbs (find) match type with ditransitive verb + indirect object (give people)!

Both lack argument ahead and behind – it seems types are defined by missing arguments!

9.2 Formal rules [Ajdukiewicz, 1935, Bar-Hillel, 1953]

Formalize set of categories C as follows – clauses with various unmet requirements:

1. every U is in C, for some set U of primitive categories;
2. every $C \times O \times C$ is in C, for some set O of type-combining operators;
3. nothing else is in C

Define **primitive categories** $U = \{\mathbf{N}, \mathbf{V}\}$:

- **N**: noun-headed category with no missing arguments (noun phrase)

- **V**: verb-headed category with no missing arguments (sentence)

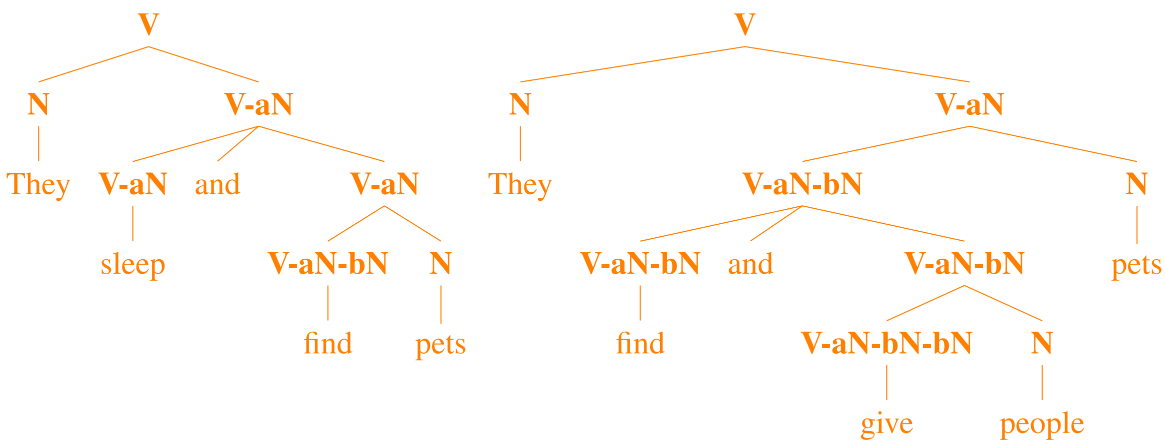
Define **type-combining operators** $O = \{\textbf{-a}, \textbf{-b}\}$:

- $\langle \alpha\textbf{-a}\beta \rangle$: α lacking β argument ahead (e.g. **V-aN** for intransitive δ above)
- $\langle \alpha\textbf{-b}\beta \rangle$: α lacking β argument behind (e.g. **V-aN-bN** for transitive η above)

Now we can define **'context-free' rules** R over these categories:

- $\langle \alpha \rangle \rightarrow \langle \beta \rangle \; \langle \alpha\textbf{-a}\beta \rangle$: argument attachment ahead
- $\langle \alpha \rangle \rightarrow \langle \alpha\textbf{-b}\beta \rangle \; \langle \beta \rangle$: argument attachment behind
- $\langle \alpha \rangle \rightarrow \langle \alpha \rangle$ and $\langle \alpha \rangle$: conjunction

These three rules model all of the above sentences:



Also note that the parents in these rules all have simpler types than the children.

This means for any lexicon (constraining types at tree leaves), the set of categories C is finite.

9.3 Non-local rules [Gazdar et al., 1985, Pollard and Sag, 1994]

Natural languages may also use non-local dependencies.

In English, these show up in topicalization, which seem to use a gap '_' at one argument:

- These pets, you say they found _.

These coordinate as well, but our test shows categories with gaps differ from those without:

- These pets, you $[_\delta$ $[_\delta$ say they found _] and $[_\delta$ think _ gave people joy]]. – sounds ok
- *These pets, you $[_\delta$ $[_{\textbf{V-aN}}$ say they found pets] and $[_\delta$ think _ gave people joy]]. – wrong

We can model this by adding a **new type-combining operator** for non-local dependencies:

- $\langle \alpha\textbf{-g}\beta \rangle$: α lacking non-local β argument (e.g. **V-aN-gN** for intransitive δ above)

and adding rules to **introduce** non-local dependencies:

- $\langle\alpha\textbf{-g}\beta\rangle \rightarrow \langle\alpha\textbf{-a}\beta\rangle$: introduce non-local dependency to argument ahead
- $\langle\alpha\textbf{-g}\beta\rangle \rightarrow \langle\alpha\textbf{-b}\beta\rangle$: introduce non-local dependency to argument behind

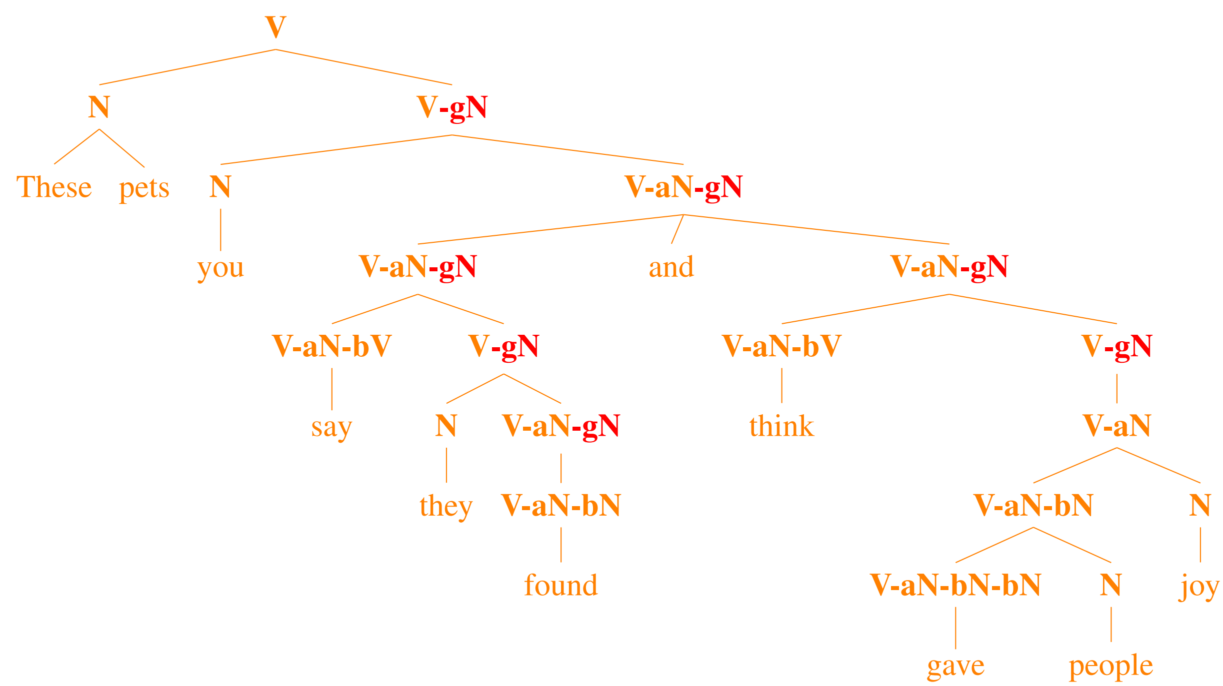
and adding rules to **attach** non-local dependencies:

- $\langle\alpha\rangle \rightarrow \langle\beta\rangle\ \langle\alpha\textbf{-g}\beta\rangle$: non-local dependency attachment

and modifying existing rules to **propagate** non-local dependencies $\psi_m \in \{\textbf{-g}\} \times C$:

- $\langle\alpha\psi_{1..M}\rangle \rightarrow \langle\beta\psi_{1..m}\rangle\ \langle\alpha\textbf{-a}\beta\psi_{m+1..M}\rangle$: argument attachment ahead, with propagation
- $\langle\alpha\psi_{1..M}\rangle \rightarrow \langle\alpha\textbf{-b}\beta\psi_{1..m}\rangle\ \langle\beta\psi_{m+1..M}\rangle$: argument attachment behind, with propagation

Here's the analysis:



Note that M above is unbounded, so our rules no longer guarantee a finite set of categories.

(Any number of arguments may be extracted and propagated up from children.)

Some use evidence like this to argue language isn't context-free but mildly context-sensitive [Shieber, 1985, Joshi, 1985, Steedman, 2000].

In practice, though, we can just constrain category sets to combinations seen in training data.

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