NLP 1 - Assignment 3

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Exercise 1. Context free grammar

(a) Convert the grammar to Chomsky Normal Form.

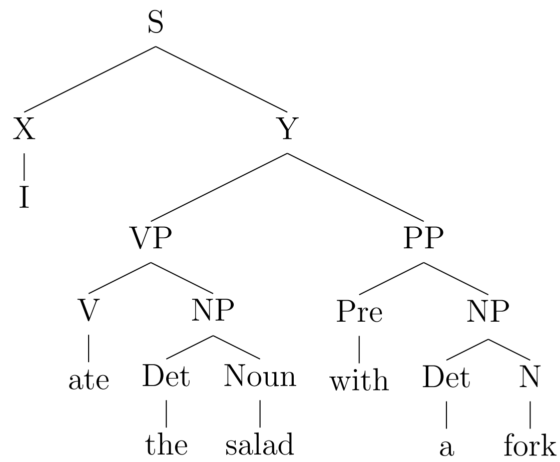
$$
\begin{aligned}
\text{S} &\rightarrow \text{NP VP} & \text{V} &\rightarrow \textit{ate} \\
\text{S} &\rightarrow \text{X Y} & \text{Det} &\rightarrow \textit{the} \mid \textit{a} \\
\text{NP} &\rightarrow \text{Det N} & \text{N} &\rightarrow \textit{fork} \mid \textit{salad} \\
\text{VP} &\rightarrow \text{V NP} & \text{Pre} &\rightarrow \textit{with} \\
\text{VP} &\rightarrow \text{V} & \text{Y} &\rightarrow \text{VP PP} \\
\text{PP} &\rightarrow \text{Pre NP} & \text{X} &\rightarrow \textit{I}
\end{aligned}
$$

(b) Use the CKY algorithm to parse the sentence, representing the CKY chart in matrix form. **I ate the salad with a fork**

I	**ate**	**the**	**salad**	**with**	**a**	**fork**
X → *I*	∅	∅	∅	∅	∅	S → X Y
	V → *ate*	∅	VP → V NP	∅	∅	Y → VP PP
		Det → *the*	NP → Det N	∅	∅	∅
			N → *salad*	∅	∅	∅
				Pre → *with*	∅	PP → Pre PP
					Det → *a*	NP → Det N
						N → *fork*

(c) Parsed trees corresponding to all possible complete analysis of **I ate the salad with a fork**

We get only one complete analysis of S, being:



Exercise 2. Tree corpus

(a) Derive a PCFG. Write down the rules and calculate their probabilities

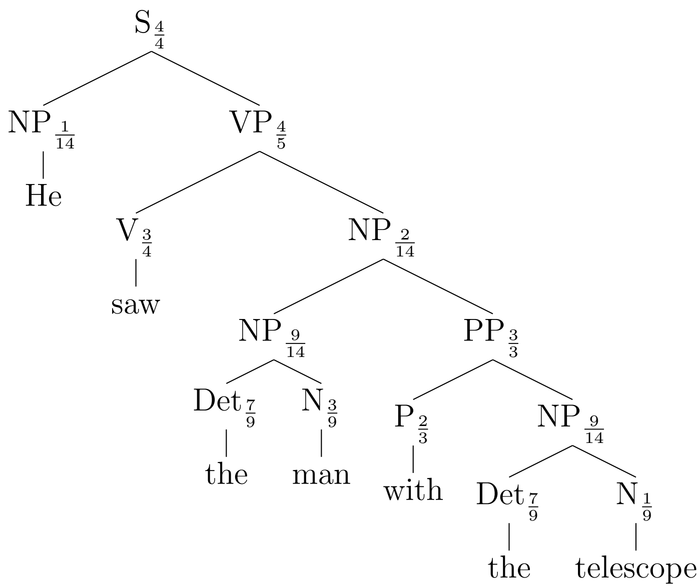
Written as Chomsky Normal Form:

S $\rightarrow$ NP VP : $\frac{4}{4}$
VP $\rightarrow$ VP PP : $\frac{1}{5}$
VP $\rightarrow$ V NP : $\frac{4}{5}$
NP $\rightarrow$ Det N : $\frac{9}{14}$
NP $\rightarrow$ NP PP : $\frac{2}{14}$
PP $\rightarrow$ P NP : $\frac{3}{3}$
NP $\rightarrow$ *She* | *Here* | *He* : $\frac{1}{14}$
V $\rightarrow$ *saw* : $\frac{3}{4}$
V $\rightarrow$ *is* : $\frac{1}{4}$

Det $\rightarrow$ *the* : $\frac{7}{9}$
Det $\rightarrow$ *a* : $\frac{2}{9}$
N $\rightarrow$ *man* : $\frac{3}{9}$
N $\rightarrow$ *girl* : $\frac{2}{9}$
N $\rightarrow$ *distance* | *telescope* | *guitar* | *flower* : $\frac{1}{9}$
P $\rightarrow$ *from* : $\frac{1}{3}$
P $\rightarrow$ *with* : $\frac{2}{3}$

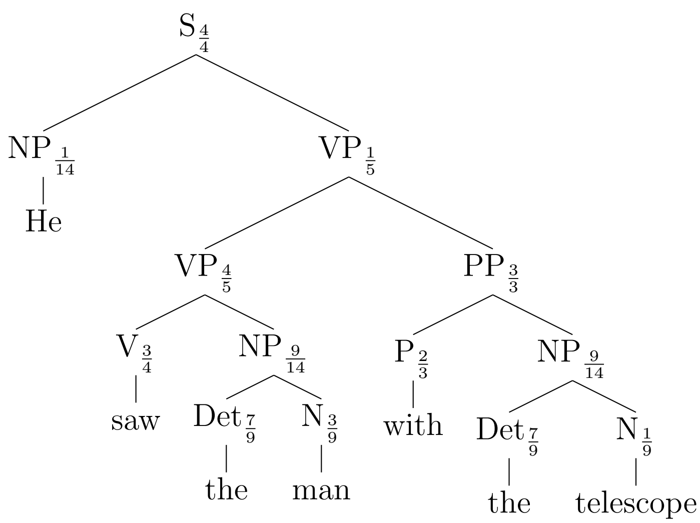
(b) Possible trees for **He saw the man with the telescope**

First option:



$$P = \frac{4}{4} \cdot \frac{1}{14} \cdot \overbrace{\frac{4}{5} \cdot \frac{3}{4} \cdot \frac{2}{14}}^{distinct} \cdot \frac{9}{14} \cdot \frac{7}{9} \cdot \frac{3}{9} \cdot \frac{3}{3} \cdot \frac{2}{3} \cdot \frac{9}{14} \cdot \frac{7}{9} \cdot \frac{1}{9} = \frac{1}{5 \cdot 14 \cdot 9 \cdot 14 \cdot 3} = \frac{1}{26460}$$

Second option:

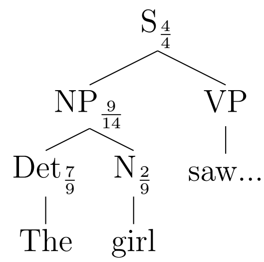


$$P = \underbrace{\frac{4}{4} \cdot \frac{1}{14}}_{sameasbefore} \cdot \overbrace{\frac{1}{5} \cdot \frac{4}{5} \cdot \frac{3}{4}}^{distinct} \cdot \underbrace{\frac{9}{14} \cdot \frac{7}{9} \cdot \frac{3}{9} \cdot \frac{3}{3} \cdot \frac{2}{3} \cdot \frac{9}{14} \cdot \frac{7}{9} \cdot \frac{1}{9}}_{sameasbefore} = \frac{1}{5 \cdot 5 \cdot 14 \cdot 2 \cdot 3 \cdot 9} = \frac{1}{18900}$$

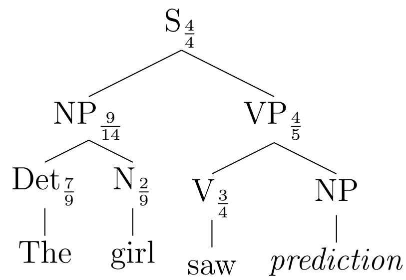
Since $26,460 > 18,900$, the second tree is more likely.

(c) Most likely completion suggestion for **The girl saw**

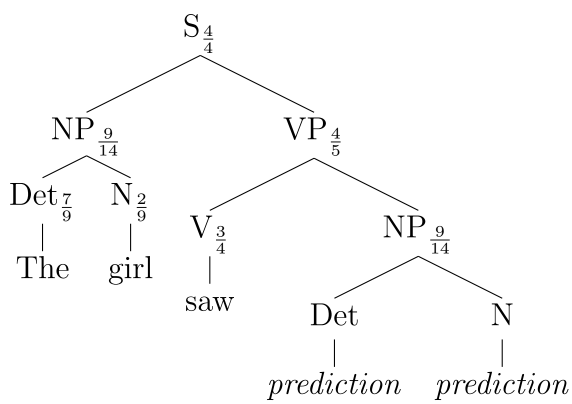
In order to make a prediction, we will first fit the existing words into a plausible tree. First, we expand $S \rightarrow NPVP$, because it is the only possibility. Moreover, the verb must be part of VP and the noun must be part of NP. Lastly, we expand NP with rule $NP \rightarrow DetN$



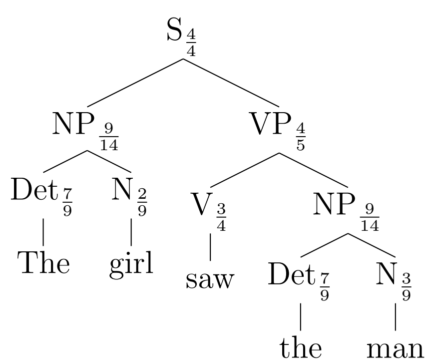
From here on we apply rules for expanding the branches by choosing the ones with highest probability. As such, we expand $VP \rightarrow VNP$ because it scores $\frac{4}{5}$



Then we select $NP \rightarrow DetN$ with $\frac{9}{14}$



Finally, we take $Det \rightarrow$ *the* and $N \rightarrow$ *man*



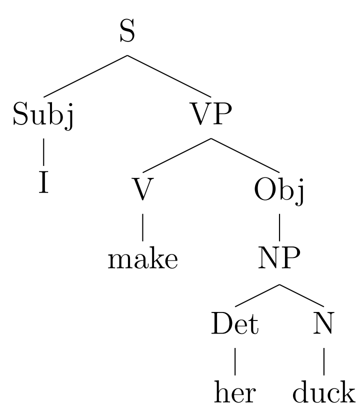
Hence, the most likely suggestion would be **The girl saw the man**. The technique for choosing the most likely rule at each step works because all the rules have probability < 1. Therefore, each rule expansion reduces the likelihood of the sentence, thus favoring short sentences. Furthermore, at each expansion, a larger rule probability produces a larger sentence probability, since both are proportional.

Exercise 3. Probabilistic Context Free Grammar

(a) Find the most probable parse for the sentence **I make her duck**

I	**make**	**her**	**duck**
Subj → *I* (0.3)	∅	S → Subj VP (0.018)	S → Subj VP (0.00288) S → Subj VP (0.018) S → Subj VP (0.00216)
	V → *make* (0.6)	VP → V Obj (0.06)	VP → V Small (0.0096) VP → V Obj (0.06) VP → V Obj Obj (0.0072)
		Obj → *her* (0.2) Det → *her* (1.0)	Small → Obj V (0.08) NP → Det N (0.25) Subj → NP (0.175) Obj → NP (0.2)
			N → *duck* (0.5) V → *duck* (0.4) NP → N (0.25) Subj → NP (0.175) Obj → NP (0.2)

The most probable parse for this sentence corresponds to the green parse with this tree:

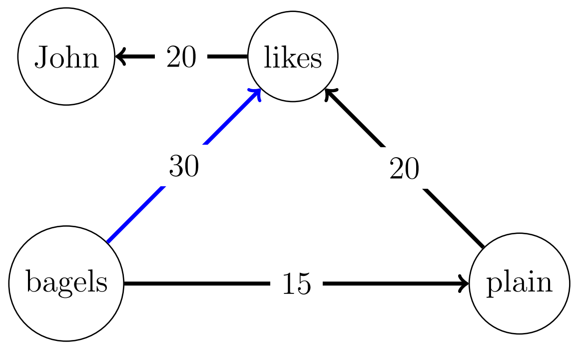


The semantic meaning is equivalent to "I make a duck. The duck is her's".

Exercise 4. Dependency parsing: MST

(a) Explain step by step how the CLE algorithm is applied

(a) Greedily select the incoming edge with the highest score, for each node.

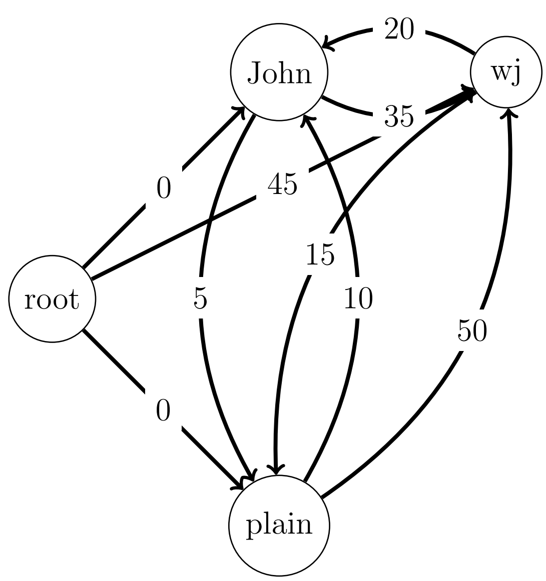


(b) We note there is a cycle and choose to contract the nodes connected by the edge in blue. We call this group w_j and recalculate its incoming and outgoing edges:

Incoming	likes $\rightarrow$ bagels	bagels $\rightarrow$ likes
root $\rightarrow$	$15 + 30 = 45$	$0 + 10 = 10$
John $\rightarrow$	$5 + 30 = 35$	$15 + 10 = 25$
plain $\rightarrow$	$20 + 30 = 50$	$5 + 10 = 15$

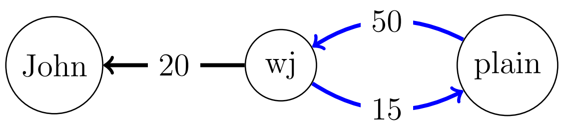
Outcoming	likes	bagels
John $\leftarrow$	20	5
plain $\leftarrow$	5	15

(c) The maximum incoming and outcoming edges per external node are marked in red. The new graph looks as follows:



	root	John	wj	plain
John	0	-	20	10
wj	45	35	-	50
plain	0	5	15	-

(d) We apply CLE recursively and go back to a) with the new graph as basis

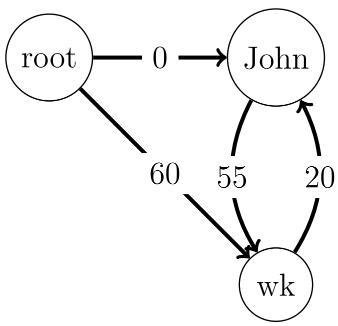


(e) Again, we have a cycle. We contract the nodes selected in blue, call it w_k and recalculate the incoming and outgoing nodes.

Incoming	wj $\rightarrow$ plain	plain $\rightarrow$ wj
root $\rightarrow$	$45 + 15 = 60$	$0 + 50 = 50$
John $\rightarrow$	$35 + 15 = 50$	$5 + 50 = 55$

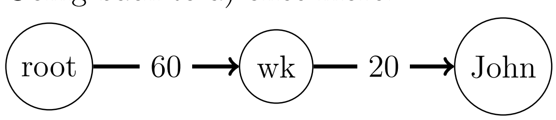
Outcoming	wj	plain
John $\leftarrow$	20	0

(f) The resulting graph is:



	root	John	wk
John	0	-	20
wk	60	55	-

(g) Going back to a) once more:

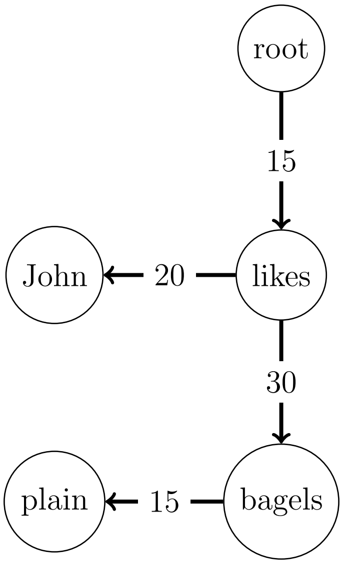


(h) Since there are no more cycles, we are done.

(b) Show the resulting MST

We interpret the previous graph and reconstruct it. Regarding wk outgoing edges, we backtrack that wk $\rightarrow$ John comes from wj $\rightarrow$ likes $\rightarrow$ John. Thus we include **likes** $\rightarrow$ **John**.

Regarding incoming edges, we backtrack that root $\rightarrow$ wk comes from root $\rightarrow$ wj $\rightarrow$ plain. On the one hand, root $\rightarrow$ wj comes from root $\rightarrow$ likes $\rightarrow$ bagels. On the other hand, wj $\rightarrow$ plain comes from bagels $\rightarrow$ plain. Thus we include **root** $\rightarrow$ **likes**, **likes** $\rightarrow$ **bagels**, and **bagels** $\rightarrow$ **plain**



Exercise 5. Dependency parsing: Transition-based
Consider the sentence: **A koala eats leafs and barks**

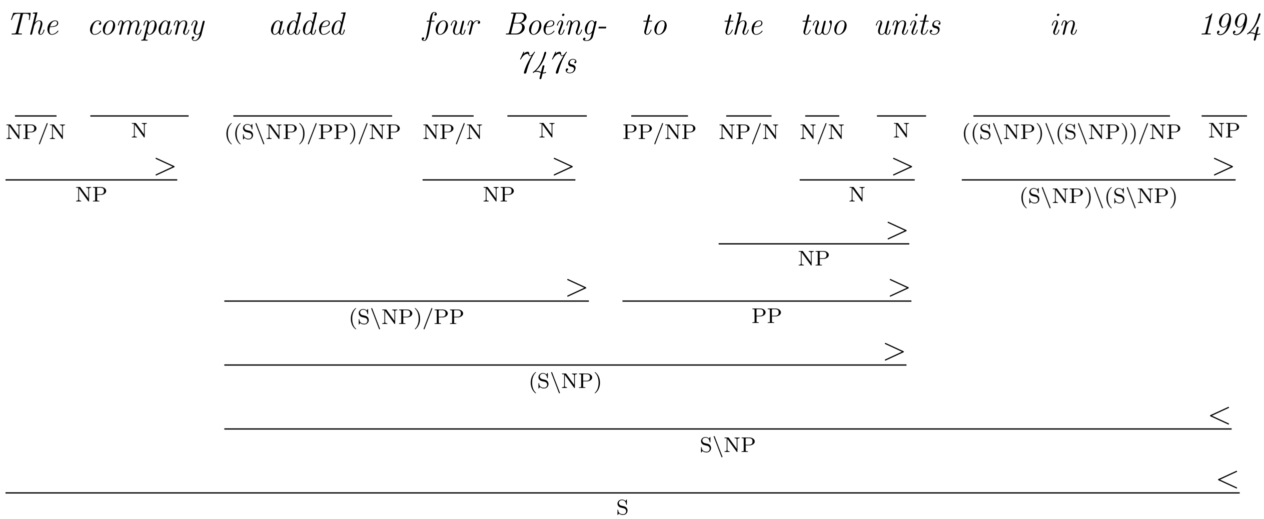
(a) Will a transition-based dependency parser be able to correctly predict this structure?
No. As seen in the next table, this transition-based dependency parser is not able to correctly predict this structure.

Transition	**Stack**	**Buffer**	**Arc set**
-	[ROOT]	A koala eats leafs and barks	∅
SHIFT	[ROOT A]	koala eats leafs and barks	∅
SHIFT	[ROOT A koala]	eats leafs and barks	∅
LEFT-ARC(det)	[ROOT koala]	eats leafs and barks	A ∪ det(koala, A)
SHIFT	[ROOT koala eats]	leafs and barks	A
LEFT-ARC(nsubj)	[ROOT eats]	leafs and barks	A ∪ nsubj(eats, koala)
RIGHT-ARC(root)	[ROOT]	leafs and barks	A ∪ root(root, eats)
SHIFT	[ROOT leafs]	and barks	A
SHIFT	[ROOT leafs and]	barks	A
RIGHT-ARC(cc)	[ROOT leafs]	barks	A ∪ cc(leafs, and)
SHIFT	[ROOT leafs barks]	∅	A
RIGHT-ARC(conj)	[ROOT leafs]	∅	A ∪ conj(leafs, barks)

(b) If there is a mistake, state what was the mistake
The arc-standard parser finds all but one arc: dobj(eats, leafs). The error arises in the configuration highlighted in red, where the parser eliminates the word *eats*, thus eliminating the possibility to connect *eats* to *leafs*. This error arises because the parser only performs local decisions, thus being ignorant to global structures.

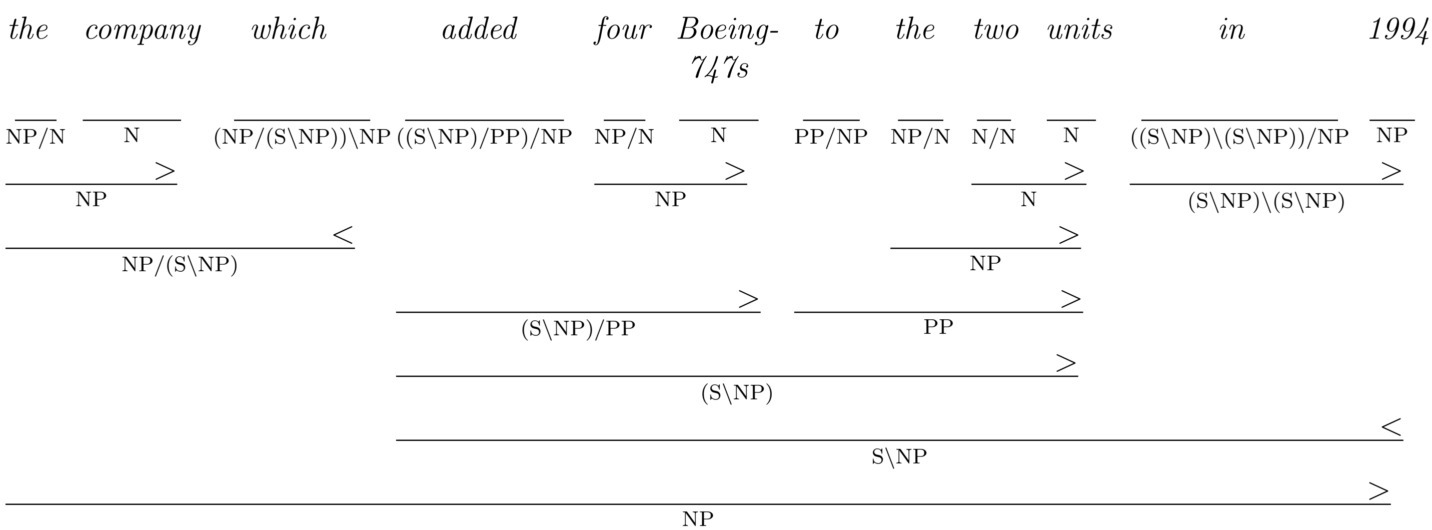
Exercise 6. CCG

(a) Derive **The company added four Boeing-747s to the two units in 1994**



(b) Derive noun phrases for **the company which added four Boeing-747s to the two units in 1994** and **the four Boeing-747s which the company added to the two units in 1994**

First case:



Here, *which* has the lexical category (NP/(S\NP))\NP. If we interpret S\NP as a VP, then the category for *which* can be interpret as:

GIVEN A NOUN PHRASE BEFORE, AND A VERB PHRASE AFTER, *which* WILL PRODUCE A NOUN PHRASE.

In order to derive the second noun phrase we had to make a couple assumptions. First, the category for *added* was changed from ((S\NP)/PP)/NP to ((S\NP)/PP). We believe that for this word, both are lexical categories valid. Second, the category for *four* was changed from NP/N to N/N. This change was inspired by looking at the category of *two*, which is equivalent to *four*.

the	*four*	*Boeing-747s*	*which*	*the*	*company*	*added*	*to*	*the*	*two*	*units*	*in*	*1994*
NP/N	N/N	N	(NP/S)\NP	NP/N	N	(S\NP)/PP	PP/NP	NP/N	N/N	N	((S\NP)\(S\NP))/NP	NP

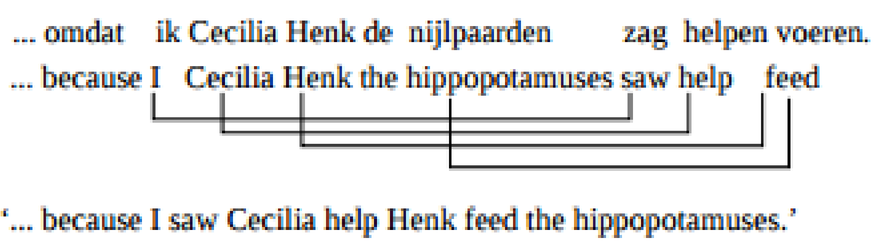
four Boeing-747s: > N
the four Boeing-747s: > NP
the four Boeing-747s which: < NP/S
the company: > NP
two units: > N
the two units: > NP
in 1994: > (S\NP)\(S\NP)
to the two units: > PP
added to the two units: > (S\NP)
added to the two units in 1994: < S\NP
the company added to the two units in 1994: < S
the four Boeing-747s which the company added to the two units in 1994: > NP

Here, *which* has the lexical category (NP/S)\NP. This time the category for *which* can be interpret as:

GIVEN A NOUN PHRASE BEFORE, AND A SENTENCE AFTER, *which* WILL PRODUCE A NOUN PHRASE.

(c) Dutch sentence that is non-context free

As taken from [1]



Where *zag*, the verb, is separated from *ik*, its subject, by 4 words forming an argument by themselves.

References

[1] Mark Steedman and Jason Baldridge. Combinatory categorial grammar. *Non-Transformational Syntax: Formal and Explicit Models of Grammar. Wiley-Blackwell*, 2011.