Parsing Beyond Context-Free Grammars: TAG: Grammar induction

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Overview

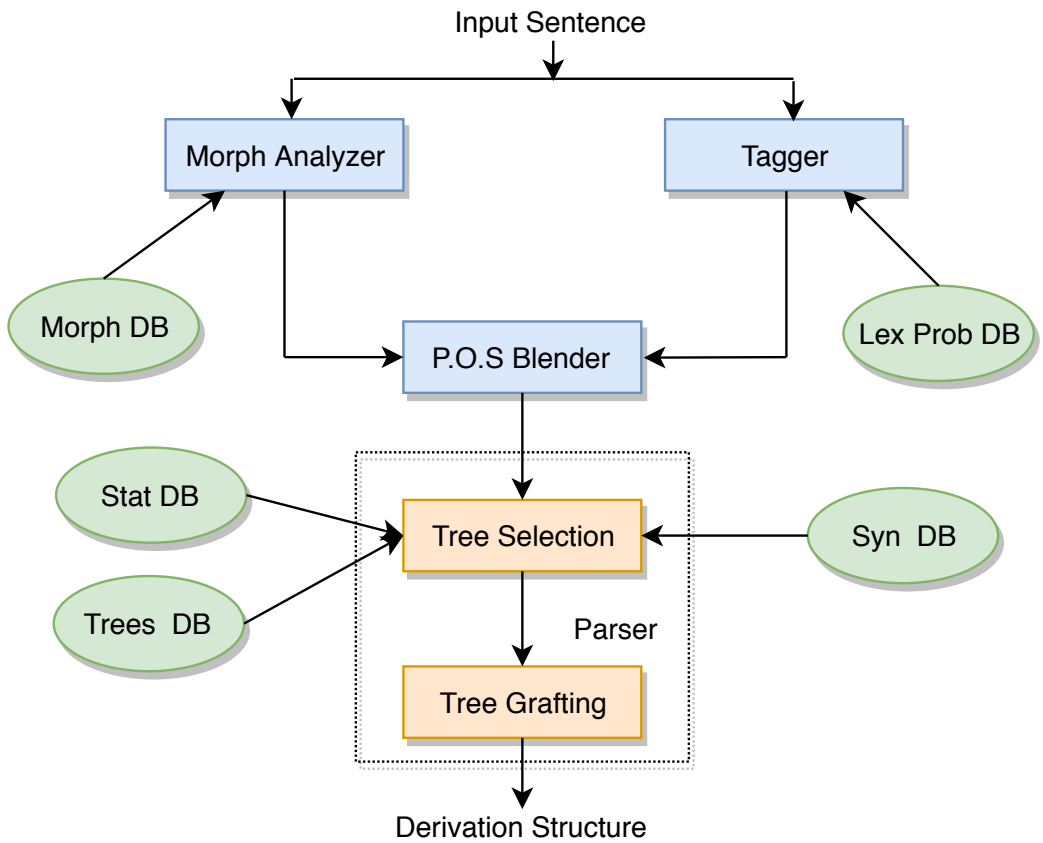
1. Hand-crafted TAGs
2. Annotated text corpora
3. TAG induction: Top-down approach
4. TAG induction: Bottom-up approach

TAG induction: motivation

- A wide-coverage TAG for a natural language contains several thousands of trees and takes a lot of effort to build
- Examples: hand-crafted TAGs for English (XTAG project [G+98]) or French (FTAG)
- Growing amount of large-scale constituency treebanks for different languages (English, German, French, Spanish, Vietnamese, Korean etc.)
- Idea: automatic induction of linguistically plausible TAGs from syntactically annotated corpora
- Orientation on already existing hand-crafted LTAGs

XTAG: LTAG implementation for English

- large coverage LTAG for English
- implemented (2001) by the XTAG Research Group at the University of Pennsylvania
- architecture [G+98]:



XTAG: facts

- Morphological Analyzer and MorphDB
  - ≈317000 inflected items derived from over 90000 stems
  - returns: root form + POS + inflectional information
- POS Tagger and Lex Prob DB
  - Wall-Street Journal trained trigram tagger
  - extended to output N-best POS sequences
- Syntactic DB
  - more than 30.000 entries, each consisting of:
    - ⋆ uninflected form of the word + POS
    - ⋆ list of trees or tree-families associated with the word
    - ⋆ list of feature equations that capture lexical idiosyncrasies

[G+98]

XTAG: facts

- Tree DB
  - 1004 unanchored trees divided into 53 families and 221 individual trees
- Tree Selection
  - for each word, tree templates are chosen from the Tree Database and the anchor position is filled with the word
- Tree Grafting
  - once a particular lexicalized tree set is schosen for a sentence, parsing is done $\Longrightarrow$ output: derived (parse) tree and derivation tree

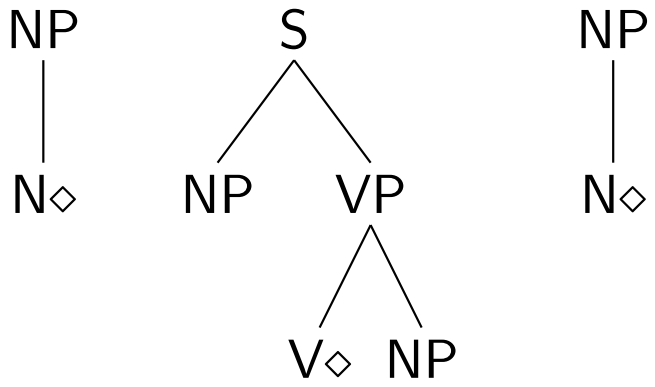
[G+98]

XTAG: Lexical anchoring

Example

(1) John likes apples

templates:

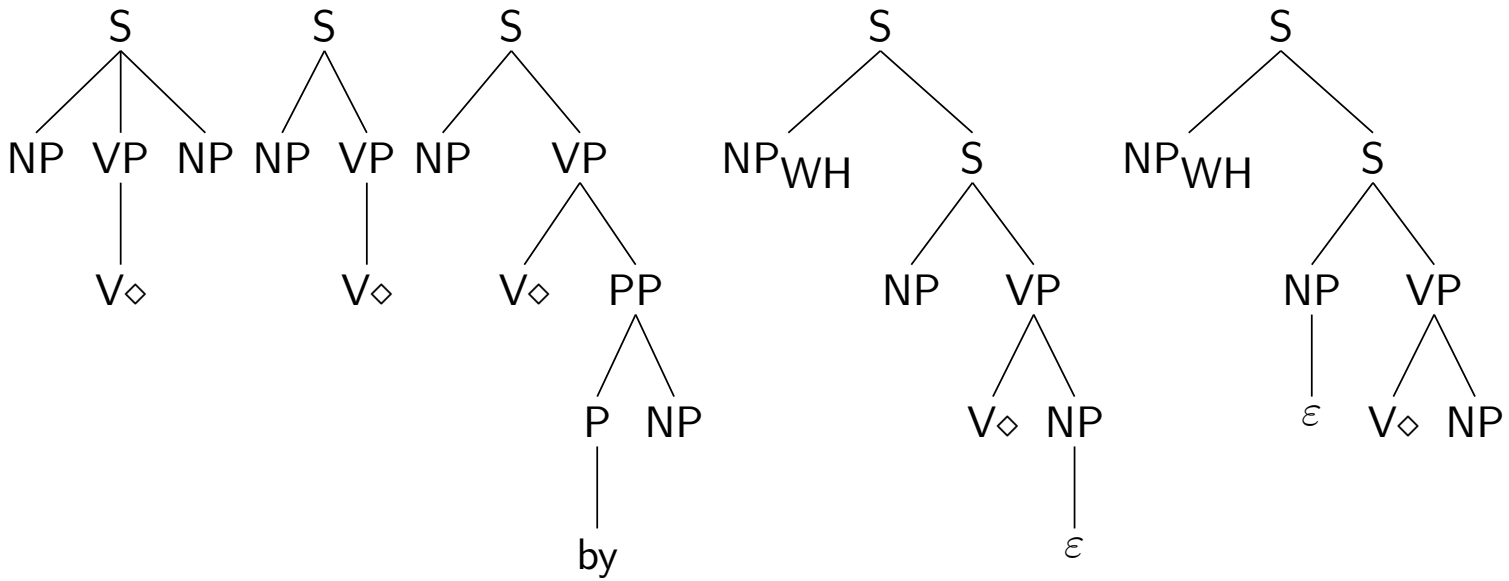


lemmas	John	like	apple
words	John	likes	apples

XTAG: tree families

- XTAG *tree families*: grouping together (unanchored) trees that belong to the same subcategorization frame

  Example: Family Tnx0Vnx1 for transitive verbs (selected trees):



  ◇ marks the position of the lexical anchor

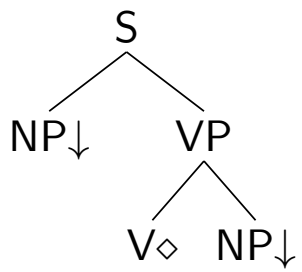
XTAG: tree families

- tree families for verb classes:
  - transitive verbs, e.g. *buy [_NP]*
    Joe bought a book.
  - ditransitive verbs, e.g. *buy [_NP _NP]*
    Joe bought Rose a book.
  - ditransitive verbs with PP, e.g. *put [_NP _PP]*
    Joe put the book on the shelf.
  - verbs with sentential complement, e.g. *tell [_NP _S]*
    Joe told Rose that Tom lives in Amsterdam.
  - light verbs, e.g. 'make comment'
    Joe made a comment on my book.
  - ...

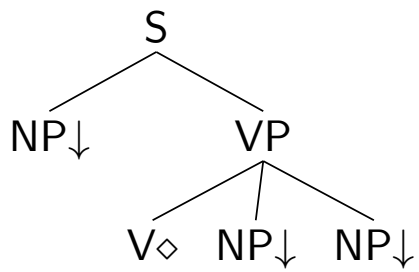
XTAG: tree families

- transitive / ditransitive / light verbs

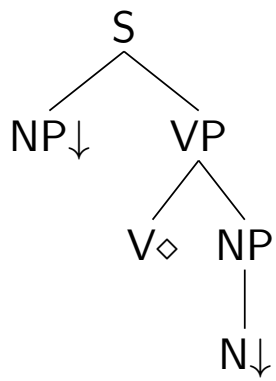
αNX0VNX1



αNX0VNX2NX1



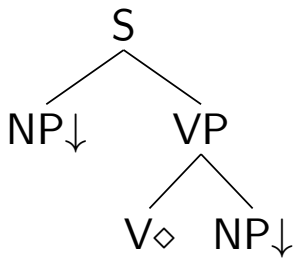
αNX0LVN1



- X◇: lexical anchor
- lexical insertion from the lexicon

XTAG: tree families

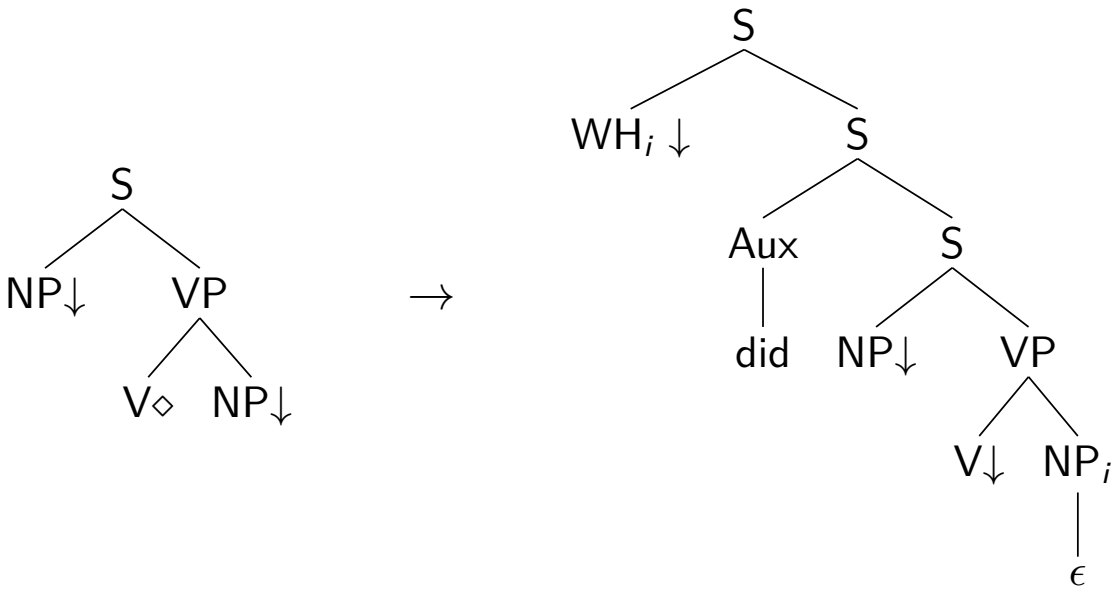
- tree family of *buy [_NP]* for
  - John bought a book.
    the 'base tree' (αNX0VNX1)



  - *Who bought a book? / What does John buy?* (wh-extraction)
  - *A book was bought by John.* (passivization)
  - *A book, Joe bought.* (topicalization)
- elementary trees derived from the base tree by transformation
- deriving *tree templates*

XTAG: tree families

- elementary trees derived from the base tree by transformation
- e.g. base tree $\rightarrow$ object extraction (wh-extraction)



XTAG: tree families

- transform base trees while changing the properties of particular words $\rightarrow$ derives a different tree family
- for example: ergative verbs as *melt*

  The sun melted the ice. $\longrightarrow$ *The ice melted.*
- XTAG covers the following phenomena:
  - wh-extraction, topicalization
  - relative clauses, raising and small clause constructions
  - clausal adjuncts and imperatives
  - it-clefts, wh-clefts
  - auxiliaries, copula, infinitives, gerunds, passives, adjuncts
  - PRO constructions, noun-noun modifications, determiner sequences
  - genitives, negation, noun-verb contractions

Syntactically annotated text corpora: treebanks

- Hand-annotated (i.e. parsed and manually corrected) corpora are used for supervised and semi-supervised training of algorithms
- Constituency based corpora: Penn Treebank (English), NeGra German Corpus, TiGer treebank, French Treebank, Korean Treebank etc.
- Different formats: bracketed sentences, XML, NeGra

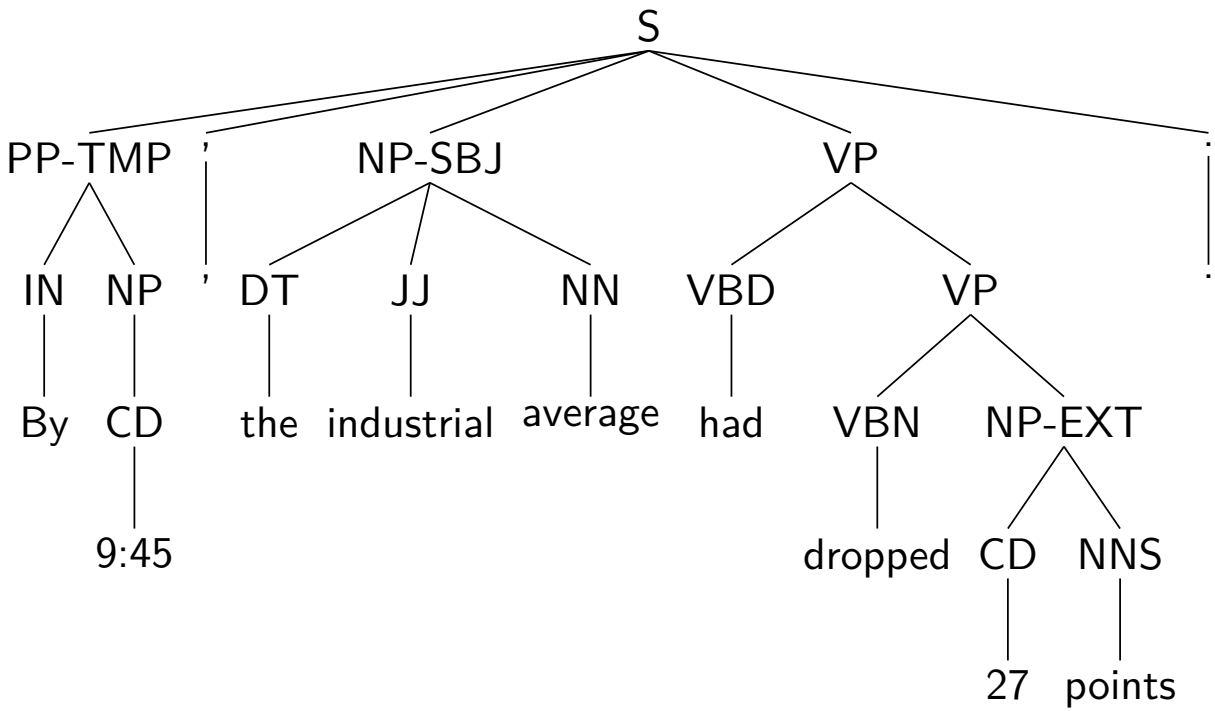
Penn Treebank

- American English, syntactically annotated corpus, constituency treebank
- Created between 1989 and 1996
- Several genres, including IBM computer manuals, nursing notes, Wall Street Journal (WSJ) articles, and transcribed telephone conversations.
- The WSJ sections constitute the most used corpus for evaluating syntactic parsing.
- Standard split of the WSJ sections: train (sec. 0–18, 38.219 sentences, 912.344 tokens), dev (sec. 19–21, 5.527 sentences, 131.768 tokens), and test (sec. 22–24, 5.462 sentences, 129.654 tokens)

[MSM93]

Penn Treebank

Sample tree:



Corresponding bracketed notation:

(S (PP-TMP (IN By) (NP (CD 9:45))) (, ,) (NP-SBJ (DT the) (JJ industrial) (NN average)) (VP (VBD had) (VP (VBN dropped) (NP-EXT (CD 27) (NNS points)))) (. .))

TAG induction: idea

- Sentences in treebanks are seen as derived TAG trees
- These derived TAG trees are cut in smaller pieces which correspond to elementary trees in TAG
- Treebanks provide additional information which can be used as features
- While extracting elementary trees we can also learn probabilities about trees (for example, statistics about frequencies of elementary trees)
- Probabilistic TAGs
- **Reversibility**

[XPJ00]

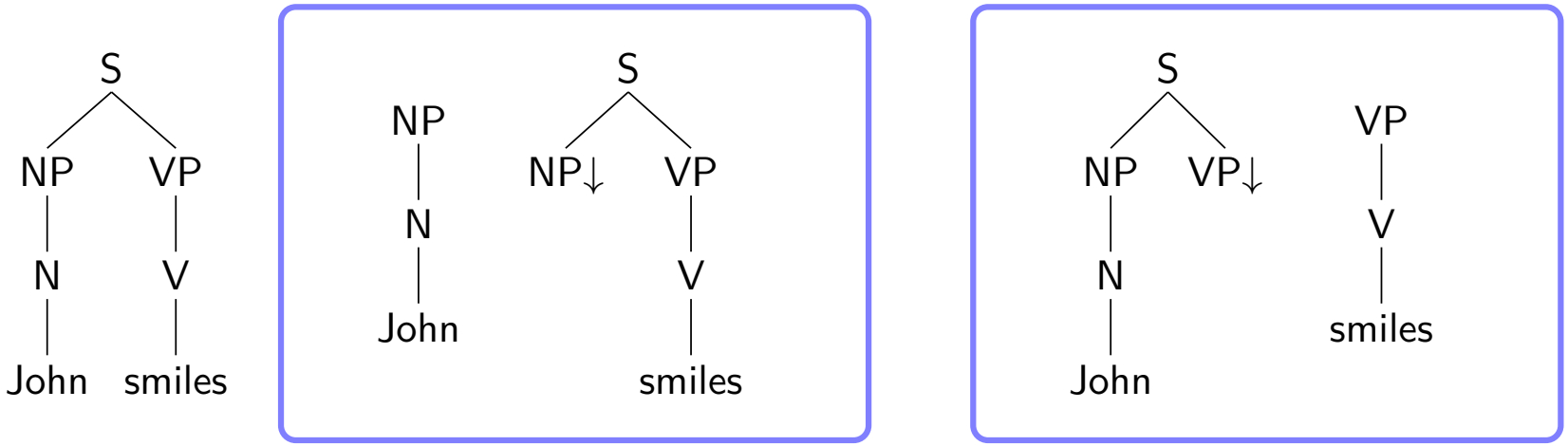
TAG induction: idea

- Annotated trees can be cut to elementary trees in different ways.
- The choice of how the elementary trees should look like depends on the grammar theory. If there is a hand-crafted TAG, it can be used as orientation.
- There are certain linguistic principles to follow:
  - Dependencies (including long-distance dependencies) should be localized in the same elementary tree (i.e. head and its complements are included into elementary tree)
  - Recursion is factored into separate auxiliary trees (i.e. modifiers are excluded)
  - No elementary tree is anchored only by an empty element.

TAG induction: idea

(2) John smiles

Two options for cutting the tree for (2) into elementary trees:



[XPJ00]

TAG induction from the PTB is usually inspired by the choices in the XTAG grammar.

LTAG extraction algorithm

Conversion of a treebank tree into elementary trees:

1. Mark children in the tree as being head, complement or modifier using heuristic percolation tables
2. Decompose tree into elementary trees

- elementary trees contain the corresponding lexical anchor and they represent a particular syntactic construction with slots for its complements
- the corresponding unanchored elementary trees are called supertags

Further step: create derivation trees based on the node addresses.

[XP06]

Percolation tables for heads and modifiers

- Percolation tables are used to mark the roles of the children in the tree
  - ⋆ Head child
  - ⋆ Syntactically obligatory child (a complement)
  - ⋆ Modifier
- Needed to extract linguistically plausible LTAGs
- Deterministic extraction procedure (only one LTAG is possible)
- Language dependent and treebank dependent
- A head can have several arguments, and its projections can be modified by other components.
  - ⋆ e.g. a verbal phrase (VP) can have a verb (V) as its head and nominal phrase (NP) as its argument
  - ⋆ a VP can be modified by adverbial phrases (APs), prepositional phrases (PPs) etc.

[XP06]

Percolation tables for heads and modifiers

- Head rules for PTB (WSJ) based on Collins (1999 p. 240) (the list is not exhaustive)

parent node	search direction	head candidates
adjp	left-to-right	nns qp nn $ advp jj vbn vbg adjp jjr np jjs dt
conjp	right-to-left	cc rb in
nac	left-to-right	nn nns nnp nnps np nac ex $ cd qp prp vbg jj jjs jjr
vp	left-to-right	to vbd vbn md vbz vb vbg vbp vp adjp nn nns np

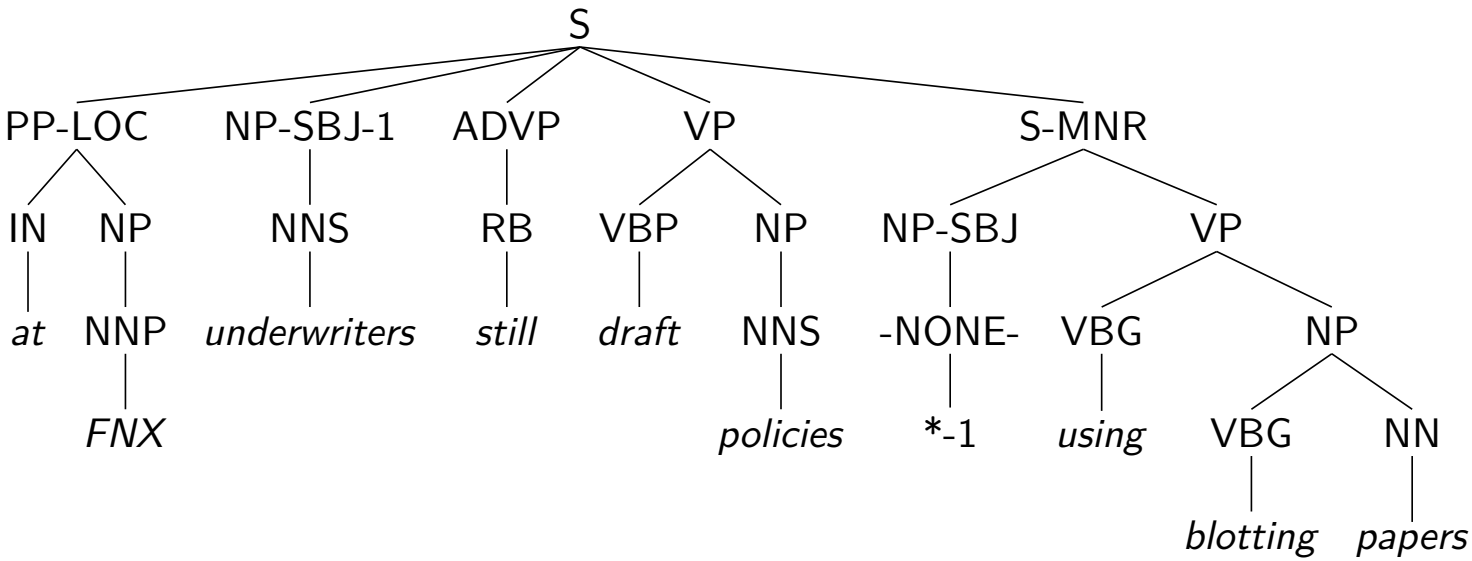
If no head can be found, the leftmost child is chosen as a default.

- Modifier rules for PTB (WSJ) (excerpt)

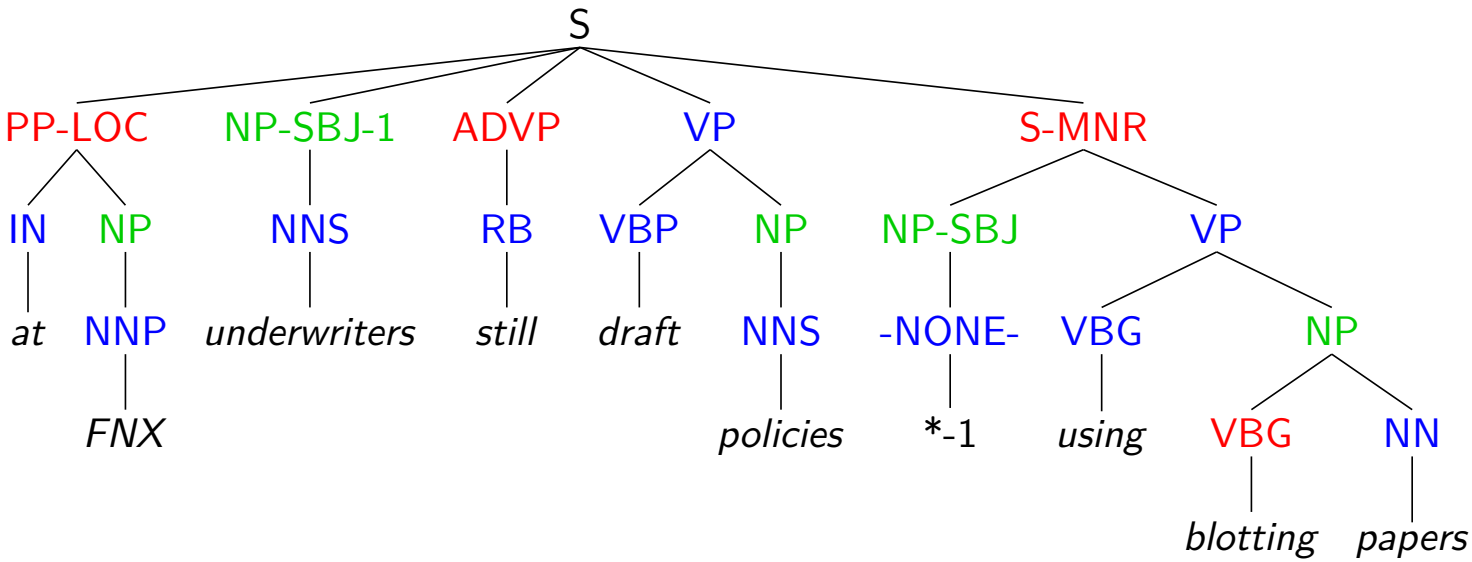
parent node	modifier nodes
s	pp pp-loc adv advp s-mnr
np	cc vbg jj jjs adjp nn np
vp	np jj jjs adjp pp-loc s-mnr

- All other nodes (non-leafs!) are marked as complements

Step 1a): Head and modifier identification



Step 1a): Head and modifier identification



Marking heads, modifiers and complements.

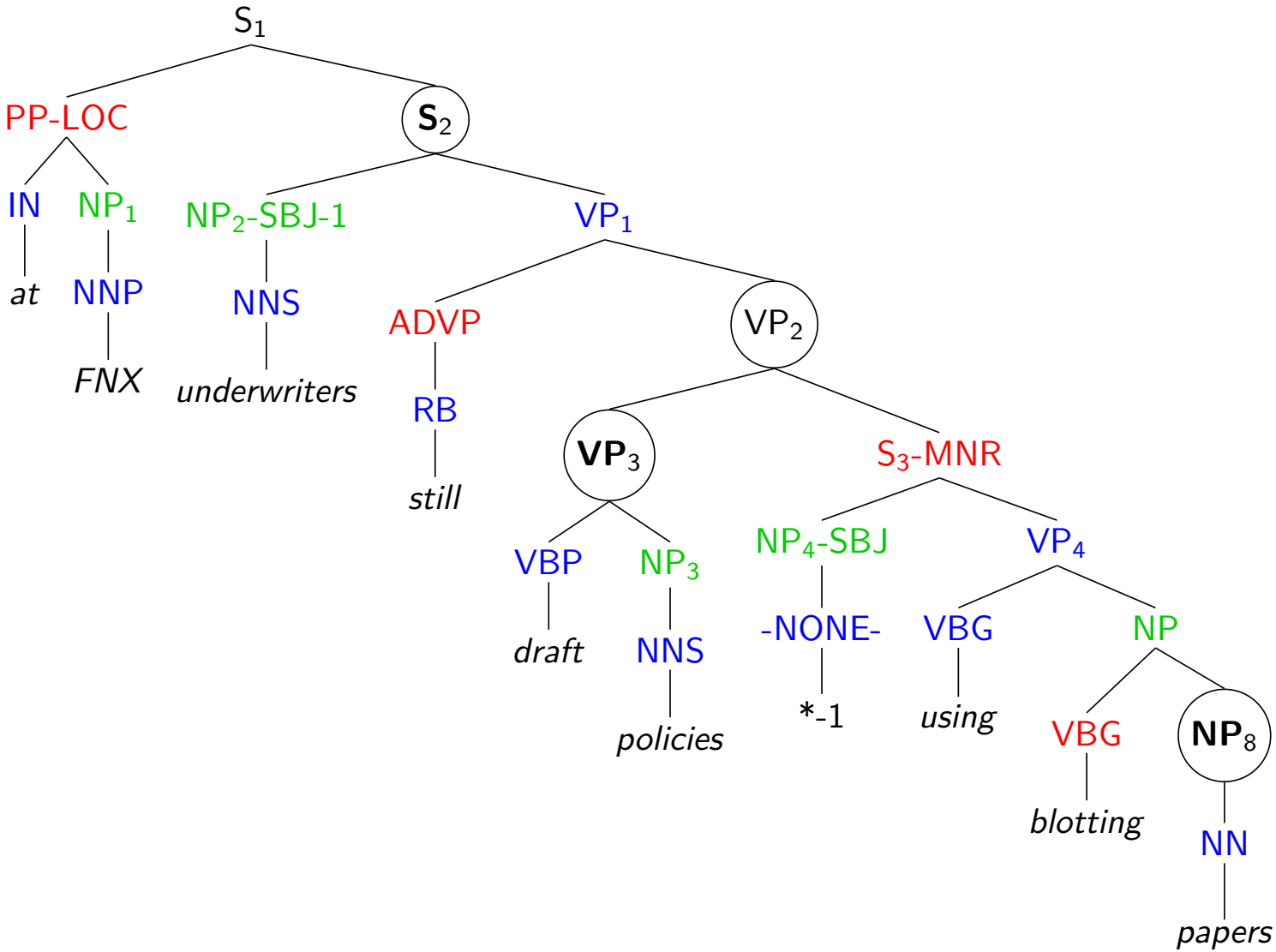
Step 1b): Bracketing around modifiers

For each subtree $v \to v_1 \dots v_n$ in the original tree, we add further bracketings whenever we encounter a modifier.

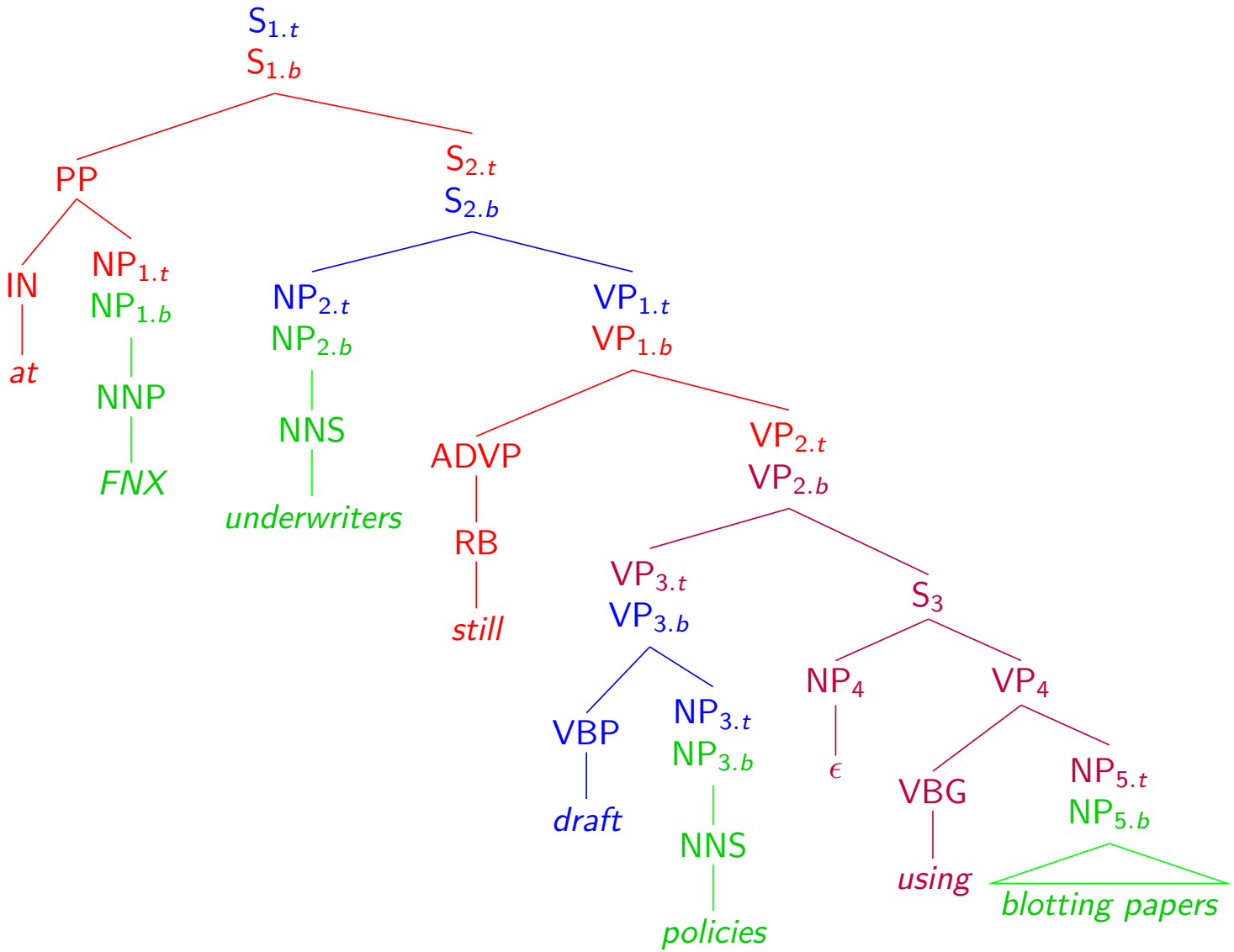
1. **(i)** For each subtree $v \to v_1 \dots v_n$:
   if v_m is the leftmost modifier, v_h is the head, and $1 < m < h$: take a new node v', replace our subtree with $v \to v_1 \dots v_{m-1} v'$ (v' is a head) and add the subtree $v' \to v_m \dots v_n$. $l(v') = l(v_h)$.
   (ii) For each subtree $v \to v_1 \dots v_n$:
   if v_1 is the leftmost modifier and either $n > 2$ or $n = 2$ and $l(v) \neq l(v_n)$: take a new node v', replace our subtree with $v \to v_1 v'$ (v' is a head) and add the subtree $v' \to v_2 \dots v_n$. $l(v') = l(v)$.
2. Repeat 1. until it cannot be applied any longer.

Then do the same (mirrored) for the modifiers to the right of the head.

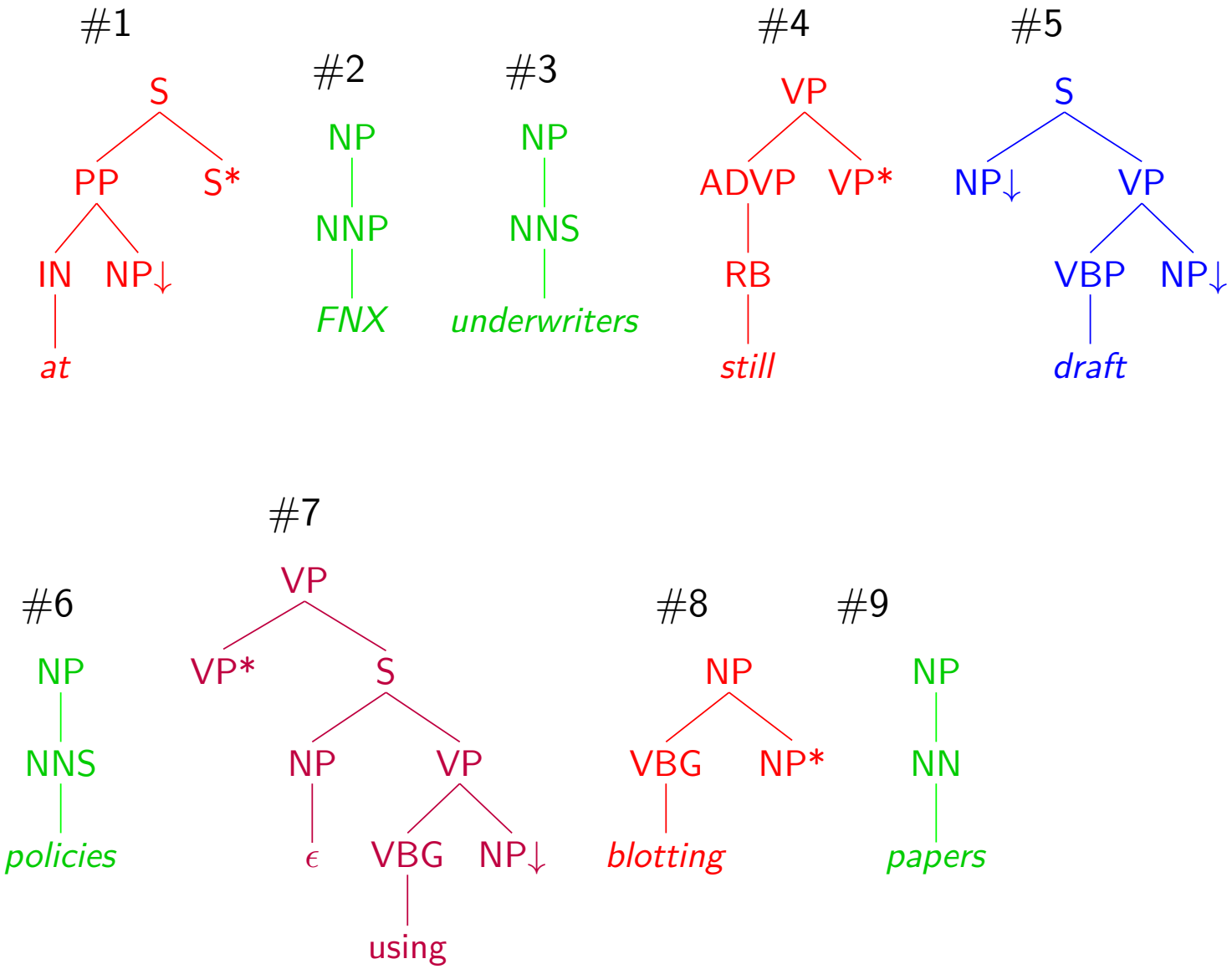
Step 1b): Bracketing around modifiers



Step 2: Extracting elementary trees



Step 2: Extracting elementary trees



Step 3: filter out linguistically implausible trees

- Linguistically implausible trees are :
  - trees with erroneous labels (e.g. an adjective erroneously marked as a preposition) ,
  - trees with an erroneously marked head child (e.g. an adjective marked as a head of an NP)
  - other trees which do not meet the criteria of the design for extracted TAG
- Filtering out implausible trees is not a trivial task
- One possibility to rule out implausible trees is to first decompose a template into a set of sub-templates then mark the template as plausible if and only if every sub-template is plausible.
- Another possibility is to manually delete the trees from the output (if possible)

Step 4: Creating derivation trees (optional)

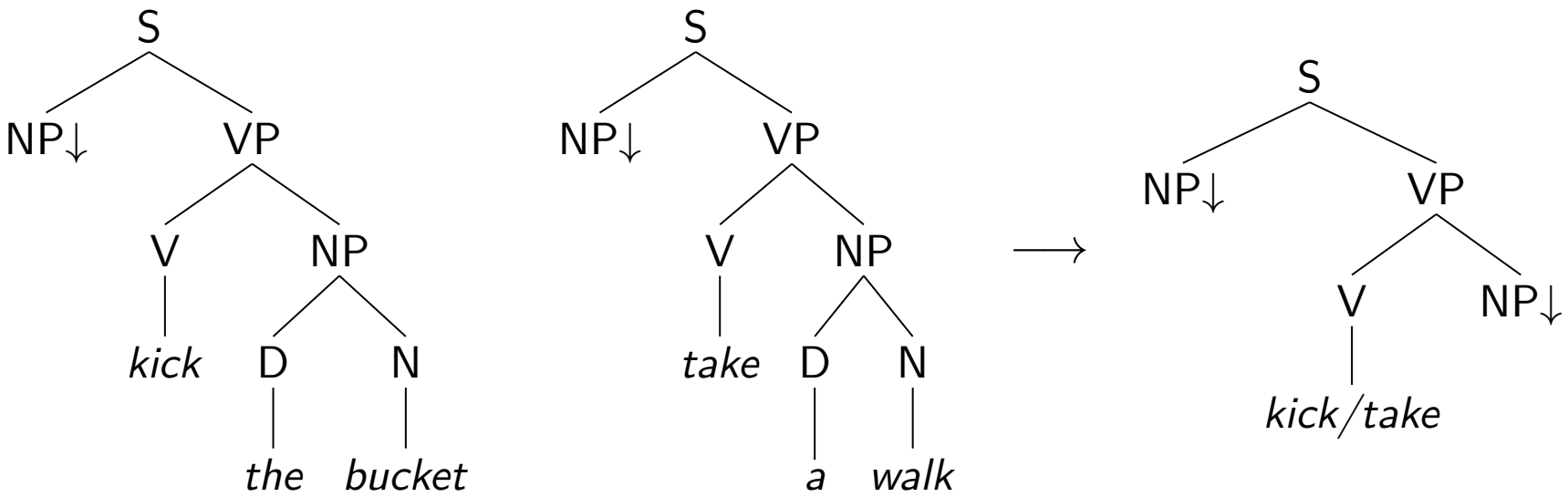
Some considerations

- It might be useful to reduce the set of the part-of-speech tags and functional tags in the treebank in order to reduce the number of elementary trees in the extracted LTAG

	tags in the PTB	**merged tags**
adjectives	JJ/JJR/JJS	A
adverbs	RB/RBR/RBS/WRB	Adv
determiners	DT/PDT/WDT/PRP$/WP$	D
nouns	CD/NN/NNS/NNP/NNPS/PRP/WP/EX/$/#	N
verbs	V/MD/VB/VBP/VBZ/VBN/VBD/VBG/TO	V
clauses	S/SQ/SBAR/SBARQ/SINV	S
noun phrases	NAC/NP/NX/QP/WHNP	NP
adjective phrases	ADJP/WHADJP	AP
adverbial phrases	ADVP/WHADVP	AdvP
preposition phrases	PP/WHPP	PP

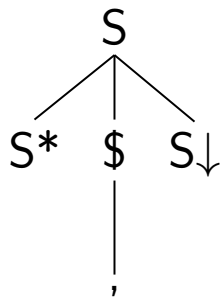
Some considerations: Co-anchors

- Although TAG elementary trees typically have one anchor, there are situations where more than one anchor could be desirable (for example, idiomatic expressions or multi-word expressions)



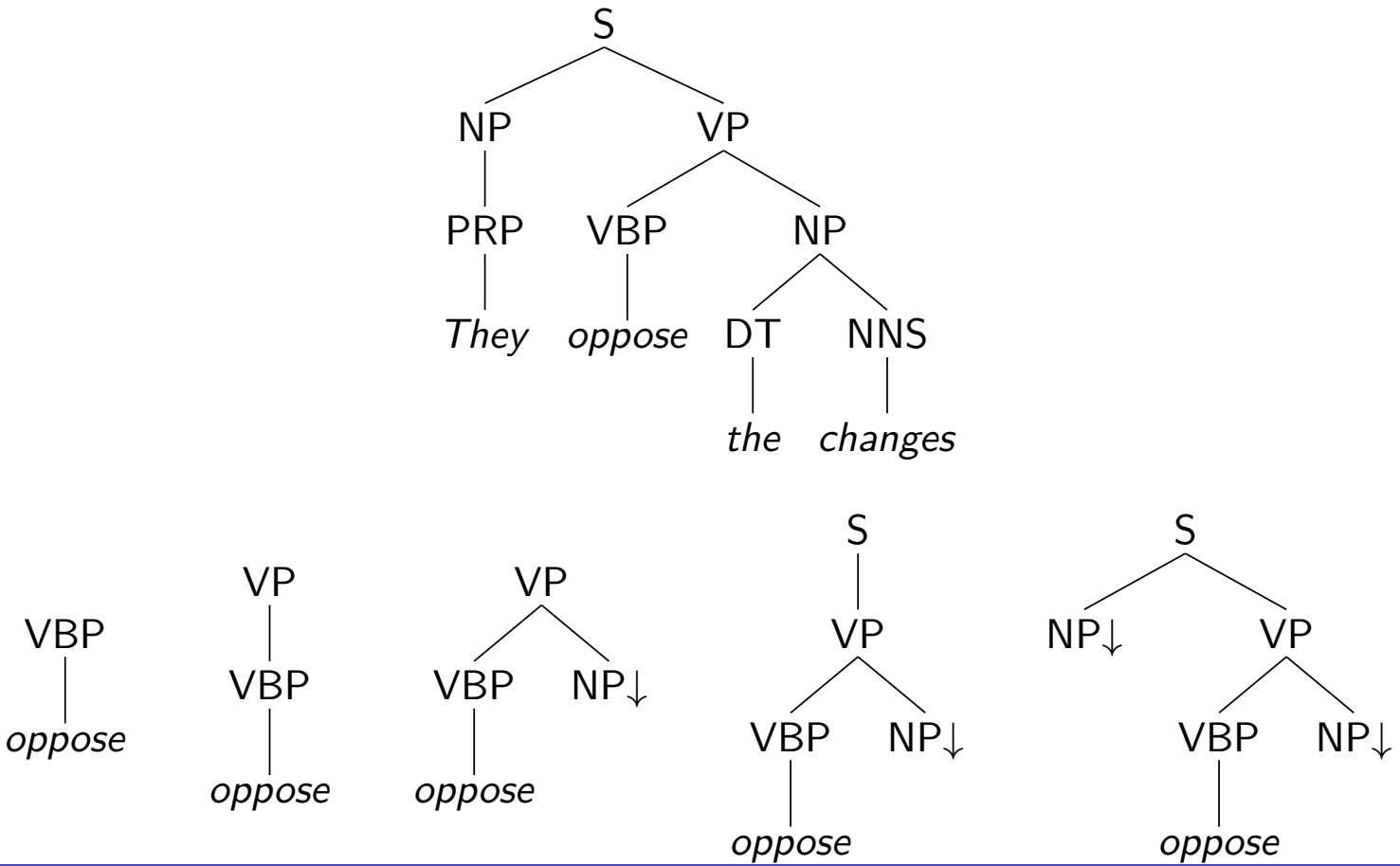
Some considerations: Punctuation

- Paired punctuation marks (e.g. quotation marks) vs. not-paired
- Punctuation marks are sometimes left out in hand-crafted LTAGs
- Paired punctuation marks are frequently beyond the TAG domain of locality.
- One way of punctuation treatment is by marking each punctuation symbol as an adjunct.



Bottom-up approach (1) [CBVS06]

- Tree-exctraction procedure is applied recursively and bottom-up
- During its application, there are multiple elementary trees in various stages are generated. [CBVS06]



Bottom-up approach (2) [CBVS06]

- One starts at the leave node and constructs the elementary tree in the following manner:
  - ⋆ extending the trunk of the partial tree by one level
  - ⋆ adding complements as substitution nodes to the root of the resulting tree
- elementary trees are extracted in parallel
- one tree is selected to be the *head partial tree* based on the roots of the partial trees and their common parent.
- a partial tree whose root is labeled as adjunct is factored into a modifier auxiliary tree that adjoines onto the head partial tree.

[CBVS06]

Bottom-up approach (algorithm) [CBVS06]

1. The procedure begins by associating an anchor (leave) and its corresponding preterminal with partial tree γ_0 . A *partial tree* is an elementary tree in a possibly completed or still incomplete stage of generation.
2. The full elementary tree is constructed bottom up from γ_0 , alternating between two steps: growing the trunk of the partial tree by one level, and adding substitution nodes as daughters of the root of the partial tree.
3. (for continuous steps, see next page)

Bottom-up approach (algorithm) [CBVS06]

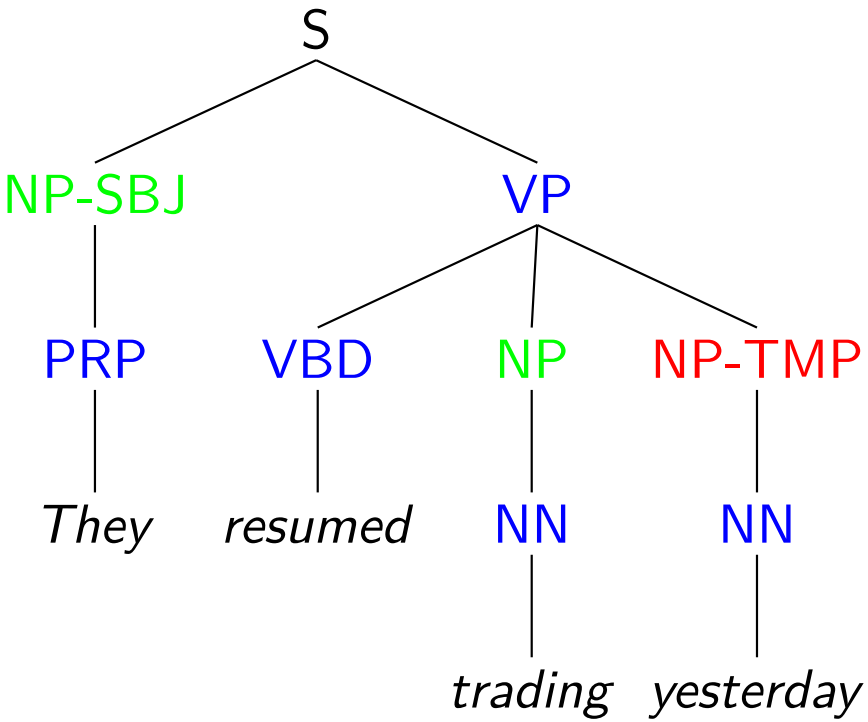
1. Let μ_1, μ_2,..., μ_n be the root nodes of sibling subtrees γ_1, γ_2,..., γ_n respectively. Let μ_p, be an immediately dominating node corresponding to these siblings' parent:
   - One partial tree μ_i is selected to be the *head partial tree* based on the roots of the partial trees and their common parent μ_p
   - Roots of the remaining partial trees are marked as complements or adjuncts
   - The head partial tree is then extended by one level
   - Duplicates are made of complement nodes such that they become substitution nodes in the head partial tree.
   - A partial tree whose root is labeled as an adjunct is factored into a modifier auxiliary tree that adjoins onto the head partial tree
   - Repeat until reaching the partial tree whose root is labeled with a start symbol and which has marked substitution sites for the arguments of the head child.

Bottom-up approach (example)

Head, modifier and complement marking has to be done, just like in the preceding algorithm. Then start with the set of all subtrees consisting of leaves and their mothers.
Repeat until there are no more trees in the set:

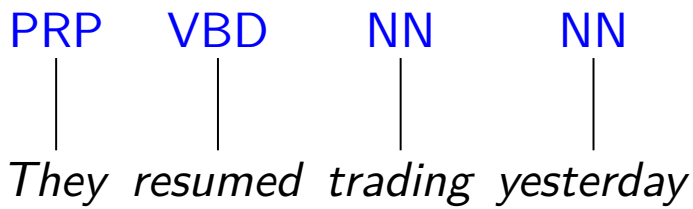
- For each tree obtained so far with root node v_r:
  - If v_r is a head:
    add its mother node and all complements among v_r's sisters to the tree;
  - If v_r is a complement or the root of the entire tree:
    move the subtree to the final grammar.
  - If v_r is a modifier to the left (resp. right) of its head sister:
    add new mother node and foot node sister to the right (resp. left) of v_r, both labeled with the label of the original mother of v_r.
    Then move the tree to the final grammar.

Bottom-up approach (example)

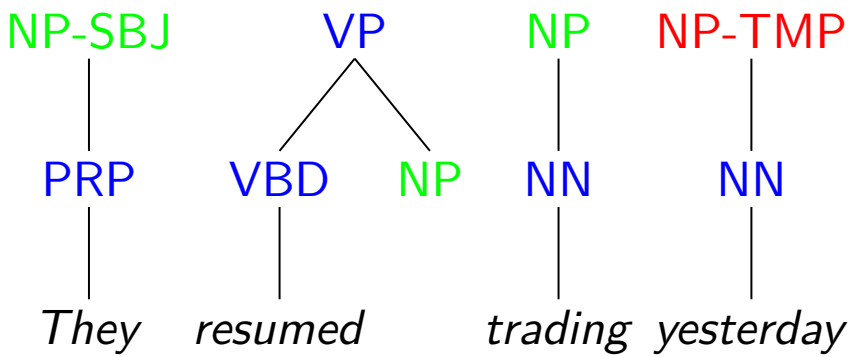


Bottom-up approach (example)

- First round of the algorithm:



- Second round of the algorithm:



[CBVS06]

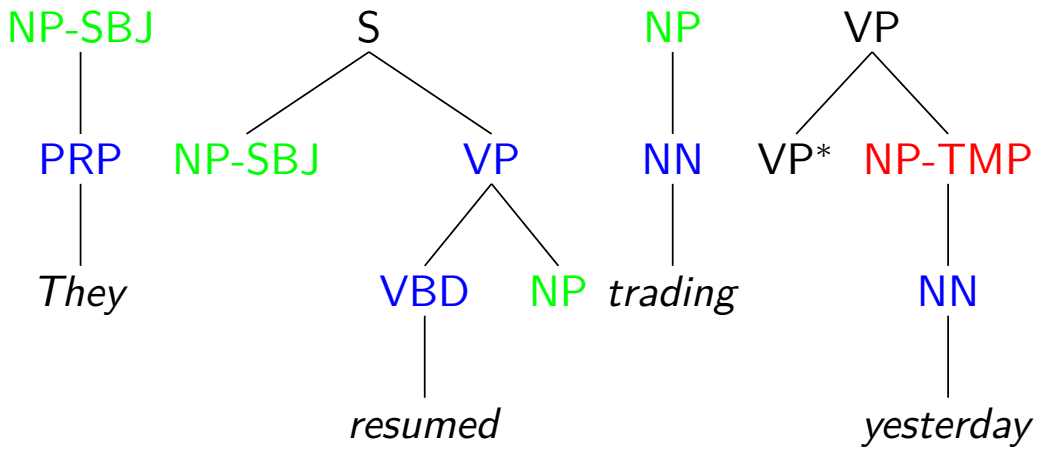
if root head:
add mother node
and complements
among sisters

if root complement:
elementary tree done

if root modifier with
mother node category X:
add new mother node
and foot node sister
both labeled X

Bottom-up approach (example)

- Third round of the algorithm:



[CBVS06]

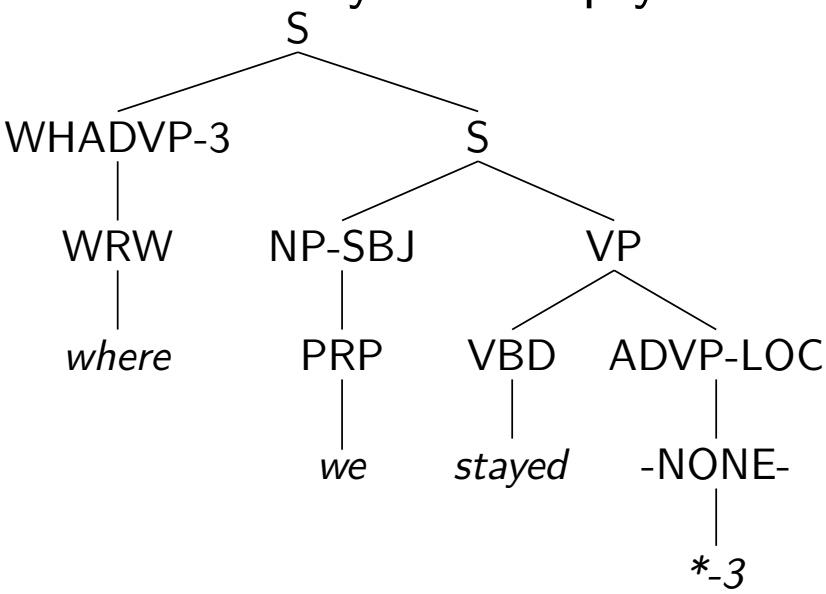
if root head:
add mother node
and complements
among sisters

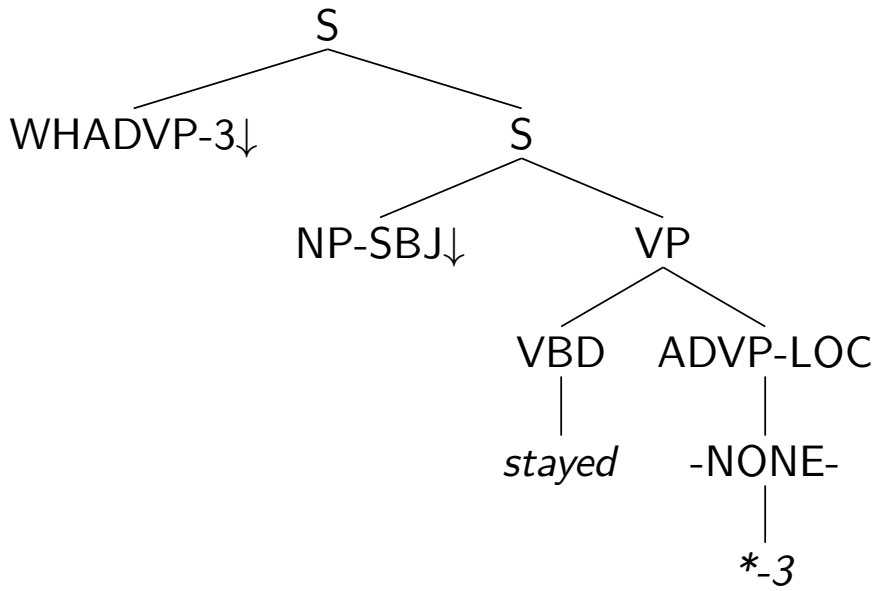
if root complement:
elementary tree done

if root modifier with
mother node category X:
add new mother node
and foot node sister
both labeled X

Some considerations: Empty elements

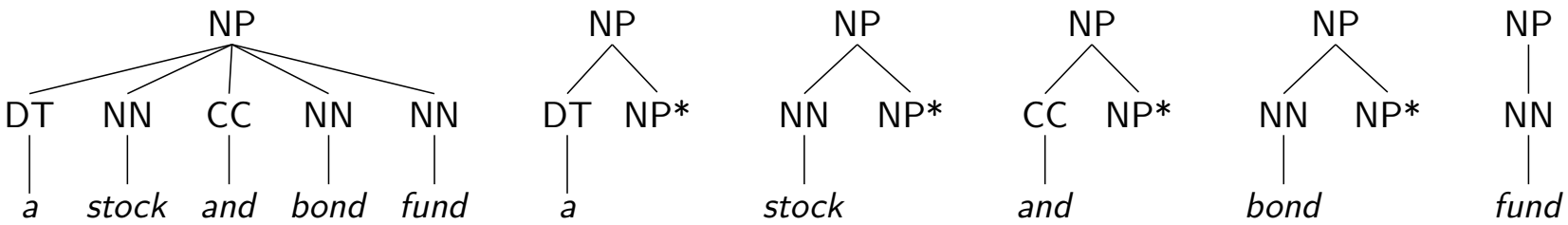
- Empty elements are terminal nodes in bracketings that do not represent lexical items
- Present in Penn Treebank and in the hand-crafted TAGs $\longrightarrow$ desirable to keep in the extracted LTAG?
- Modification of extraction algorithm can be made which grafts partial trees anchored by empty elements onto partial trees anchored by non-empty elements.





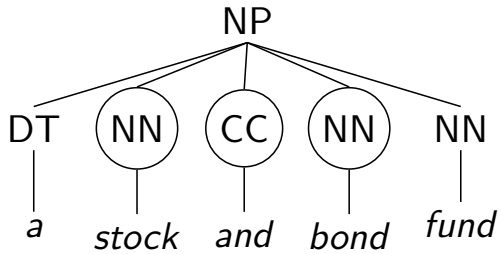
Some considerations: Conjunctions

- According to the proposed algorithm, constructions with conjunctions are treated like this:

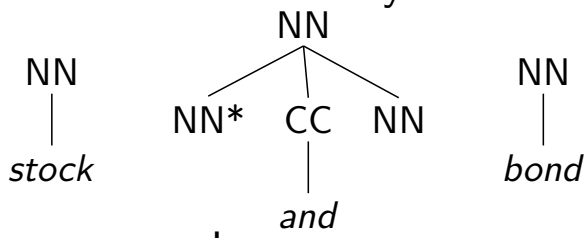


Some considerations: Conjunctions

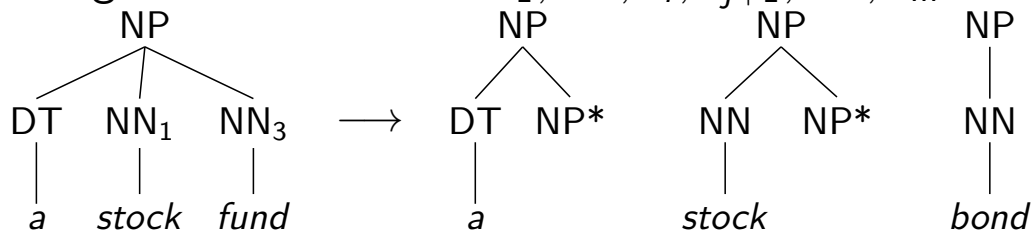
- Identify a sequence of daughters $n_1, \ldots n_j$, such that $1 \leq i < j \leq m$ representing conjuncts and associated conjunctions. n_i is the leftmost conjunct, n_j the rightmost conjunct.



- From the daughters $n_{i+1}, \ldots, n_j$ factor the conjunction into its own auxiliary tree. Auxiliary tree is anchored with conjunction. It adjoins onto n_i. Conjuncts become initial trees that substitute into the auxiliary tree.



- Default processing resumes on nodes $n_1, \ldots, n_i, n_{j+1}, \ldots, n_m$



Extracted TAGs: statistics

Parameters	**French LTAG** [BvCSK18]	**German LTAG** [Kae12]	**English LTAG** [KFM+17]
Elementary trees	5145	3426	4727
Elementary trees once	2693	1562	2165
POS tags	13 / 26	53	36
Sentences	21550	50000	44168
Avg. sentence length	31.34	17.71	appr. 20

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