Dependency Structures

Computational Linguistics

Emory University

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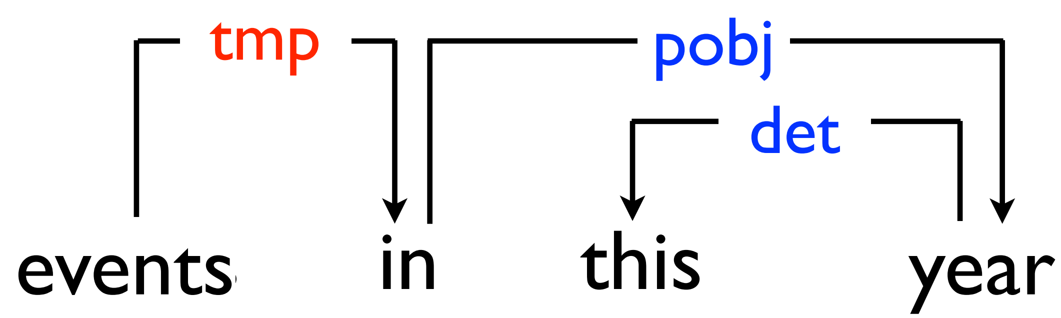
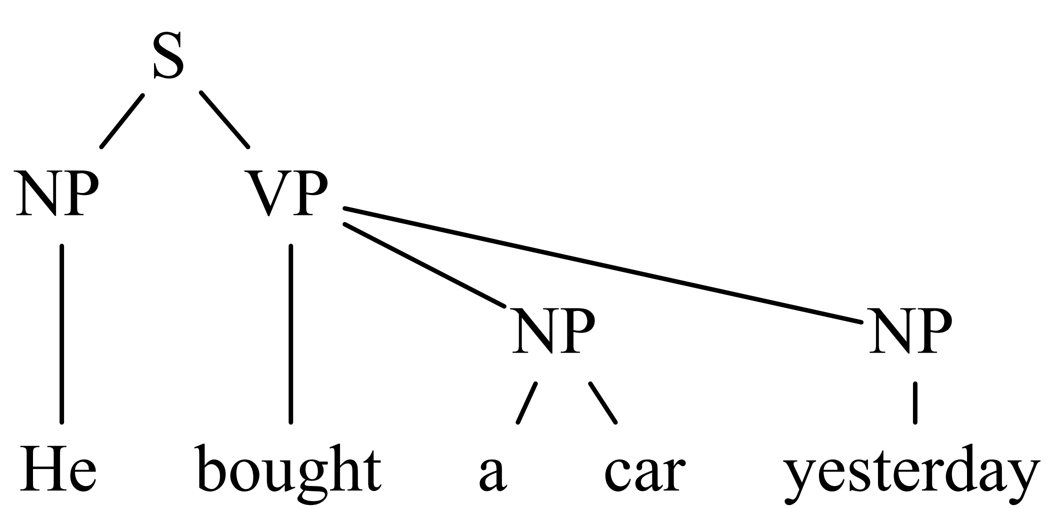
Dependency Structures

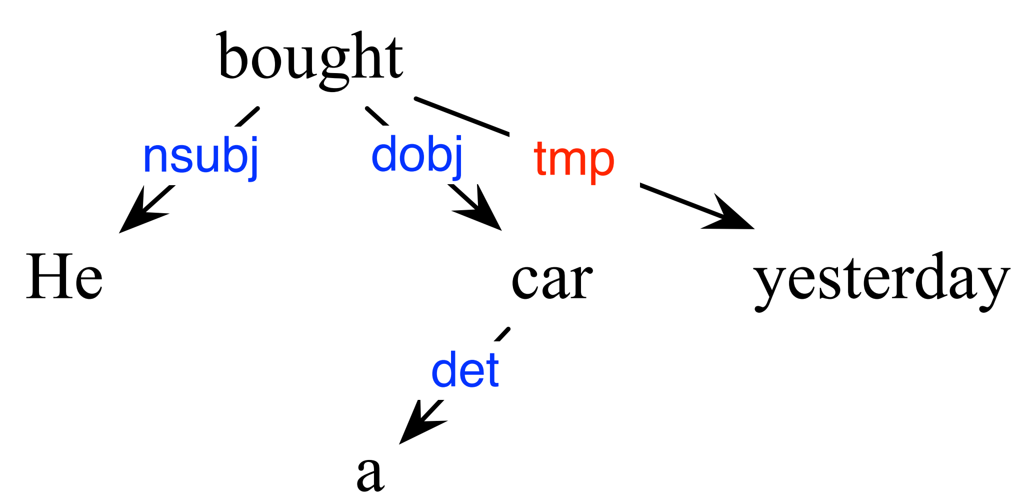
A syntactic or semantic (or other) relation between a pair of tokens.

dependency



Phrase structures vs. Dependency structures





Dependency Structures

Phrase structures

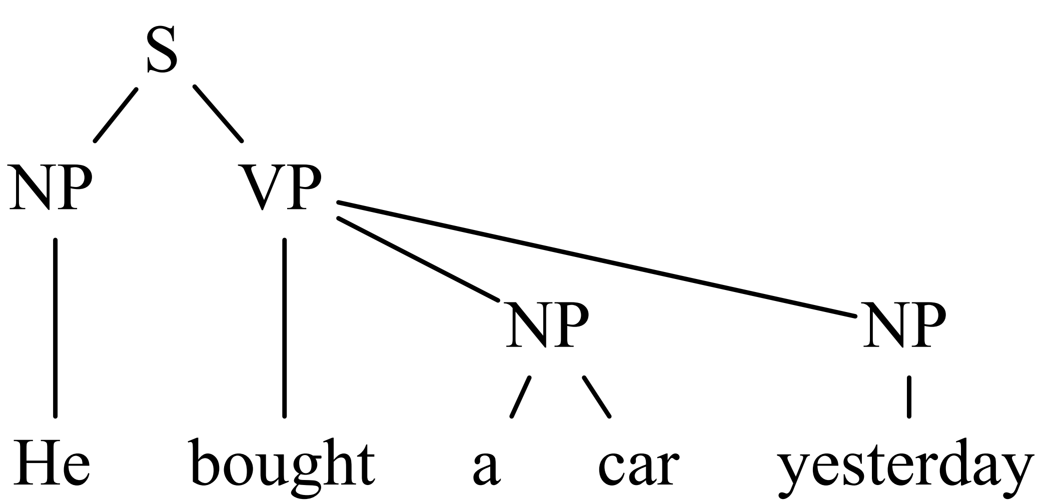
Starts with the bottom level phrases (tokens).

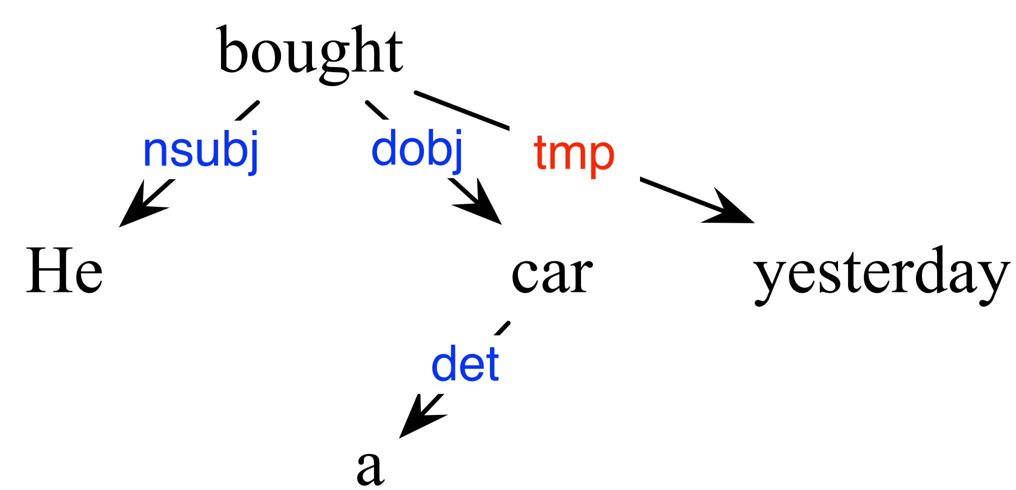
Group smaller phrases into bigger phrases.

Dependency structures

Starts with vertices (tokens).

Build a graph by adding edges between vertices (arcs).





Dependency Graph

For a sentence $s = w_1 \ldots w_n$, a dependency graph $G_s = (V_s, A_s)$

$$V_s = \{w_0 = \textbf{root}, w_1, \ldots , w_n\}$$

$$A_s = \{(w_i, w_j, r) : i \neq j, w_i \in V_s, w_j \in V_s - \{w_0\}, r \in \boxed{R_s}\}$$

set of dependency relations

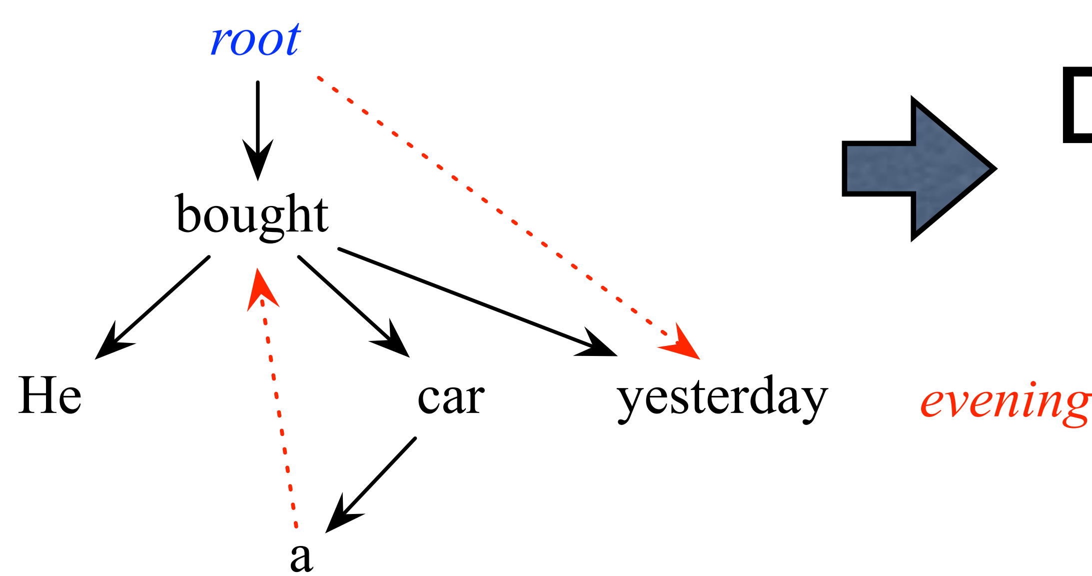
A well-formed dependency graph

Root

Single head

Connected

Acyclic



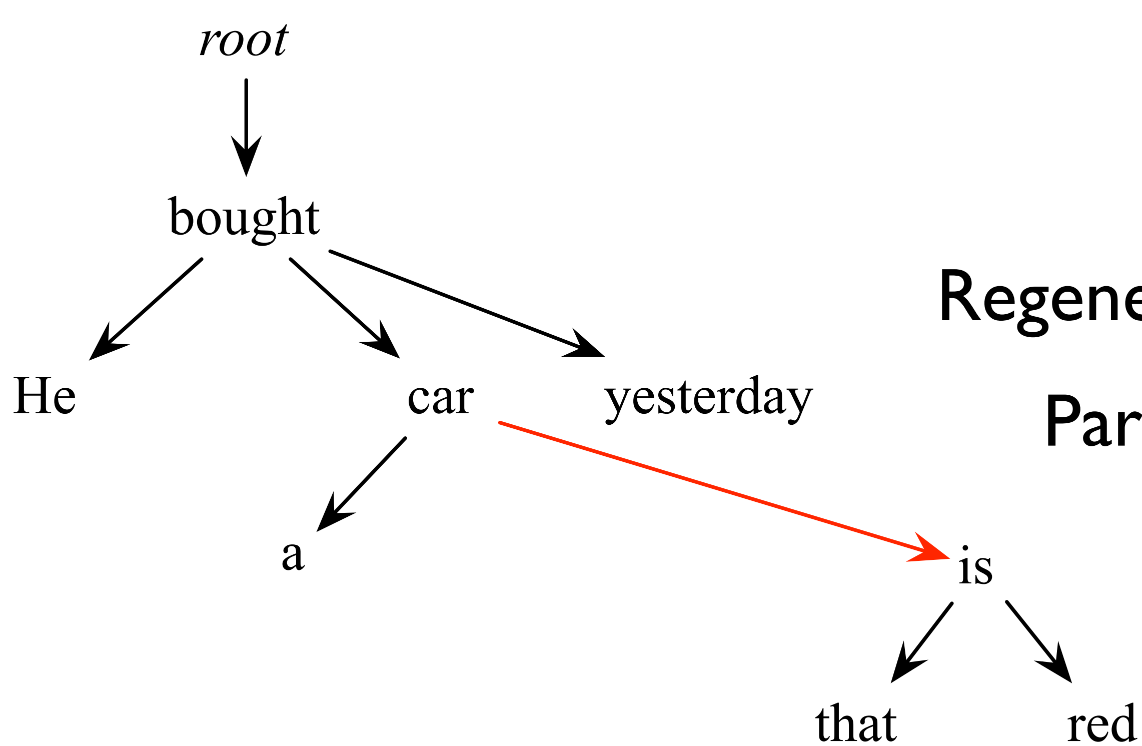
Dependency Tree

Dependency Graph

Projectivity

A projective dependency tree has no crossing arc when all vertices are lined up in linear order.

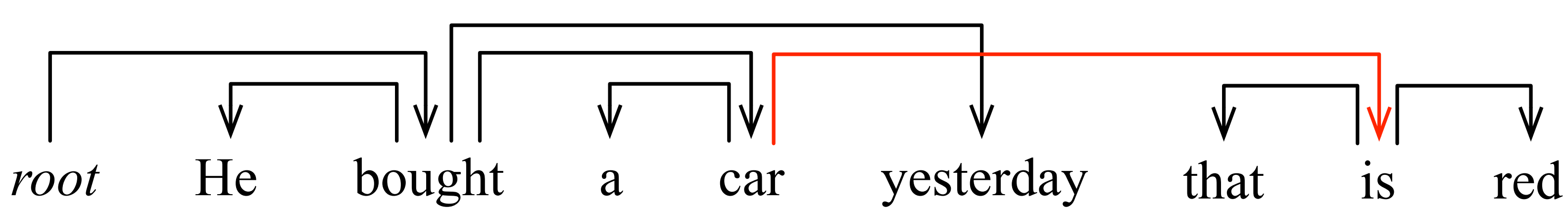
He bought a car yesterday that is red



Advantages:

Regeneration of the original sentence.

Parsing complexity: $O(n)$ vs. $O(n^2)$.



Phrase To Dependency

Phrase structures can be converted into dependency structures.

Apply head-finding rules recursively.

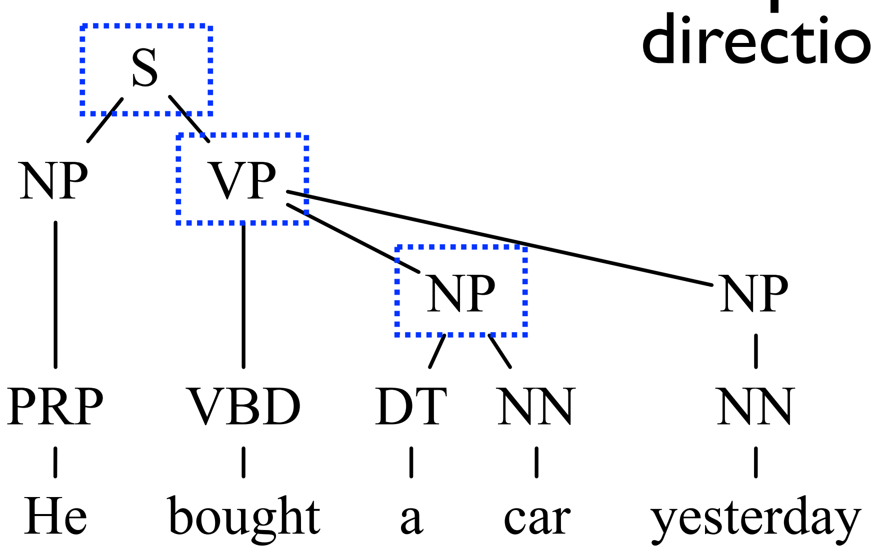
head-percolation rules, headrules

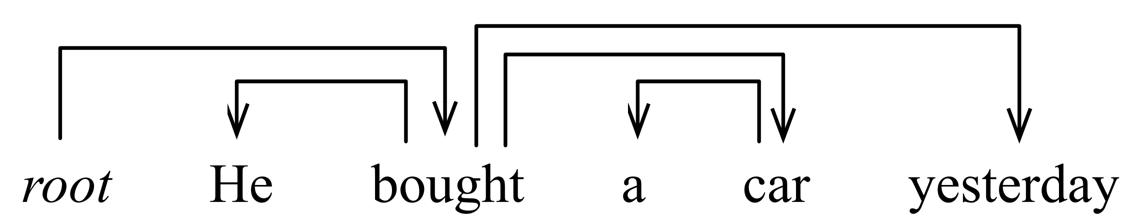
Phrase type

S	r	VP
VP	l	VB∗
NP	r	NN∗;PRP;NP

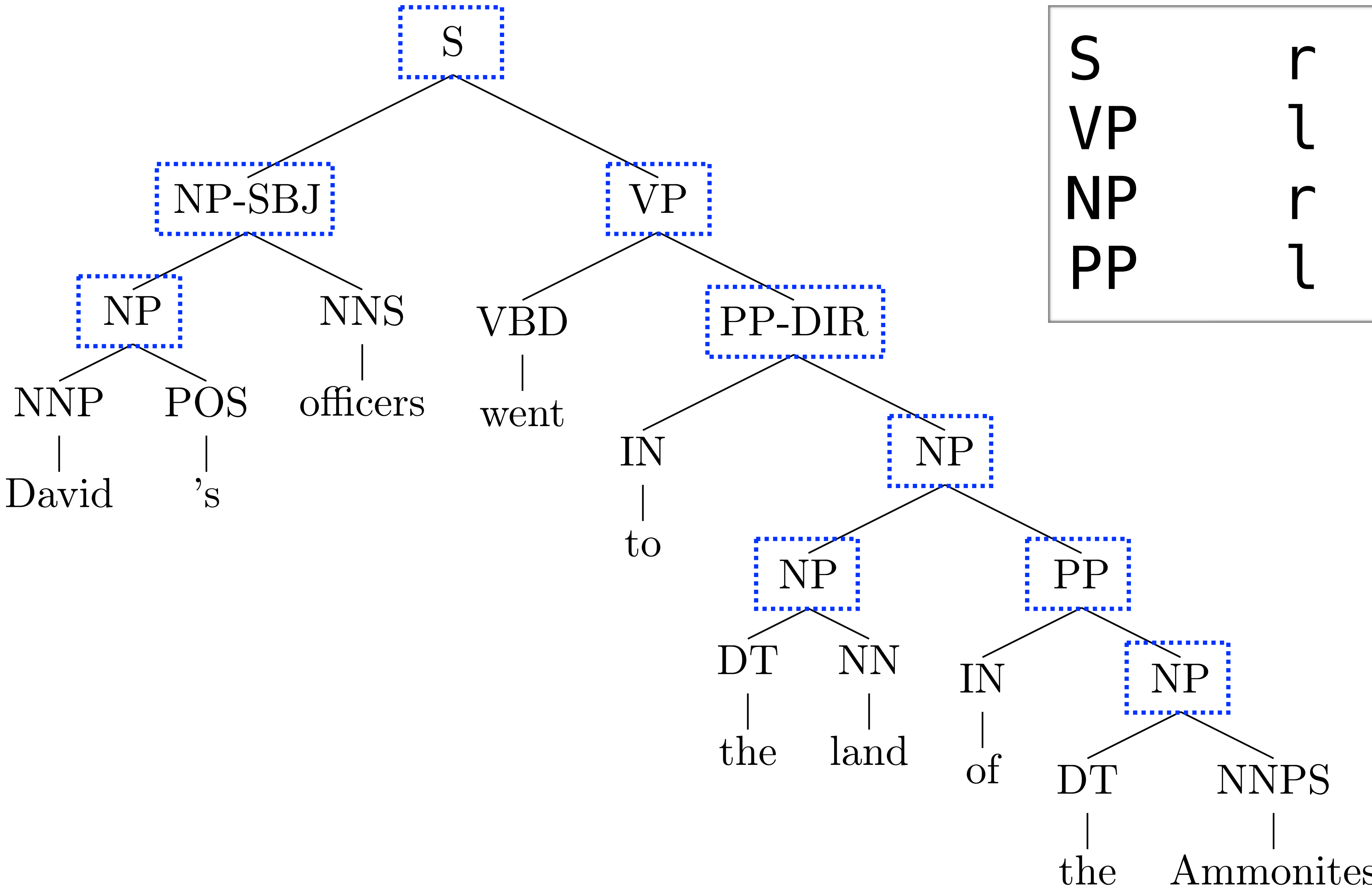
headrule

direction

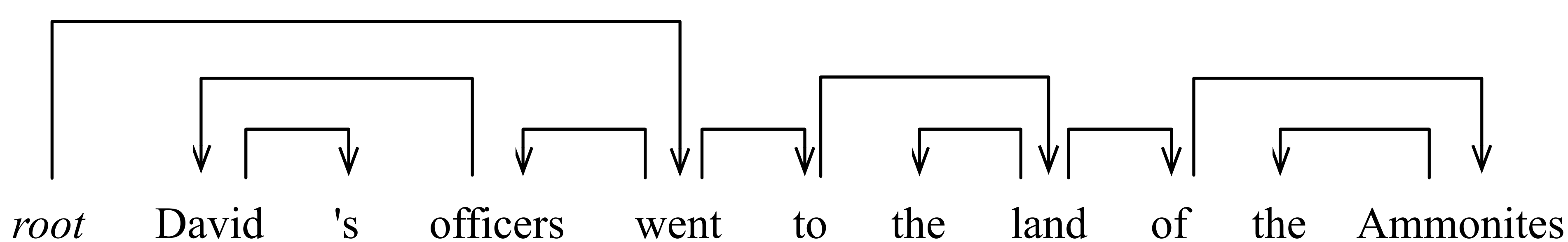




Phrase To Dependency



S	r	VP
VP	l	VB*
NP	r	NN*;PRP;NP
PP	l	IN



Attachment Scores

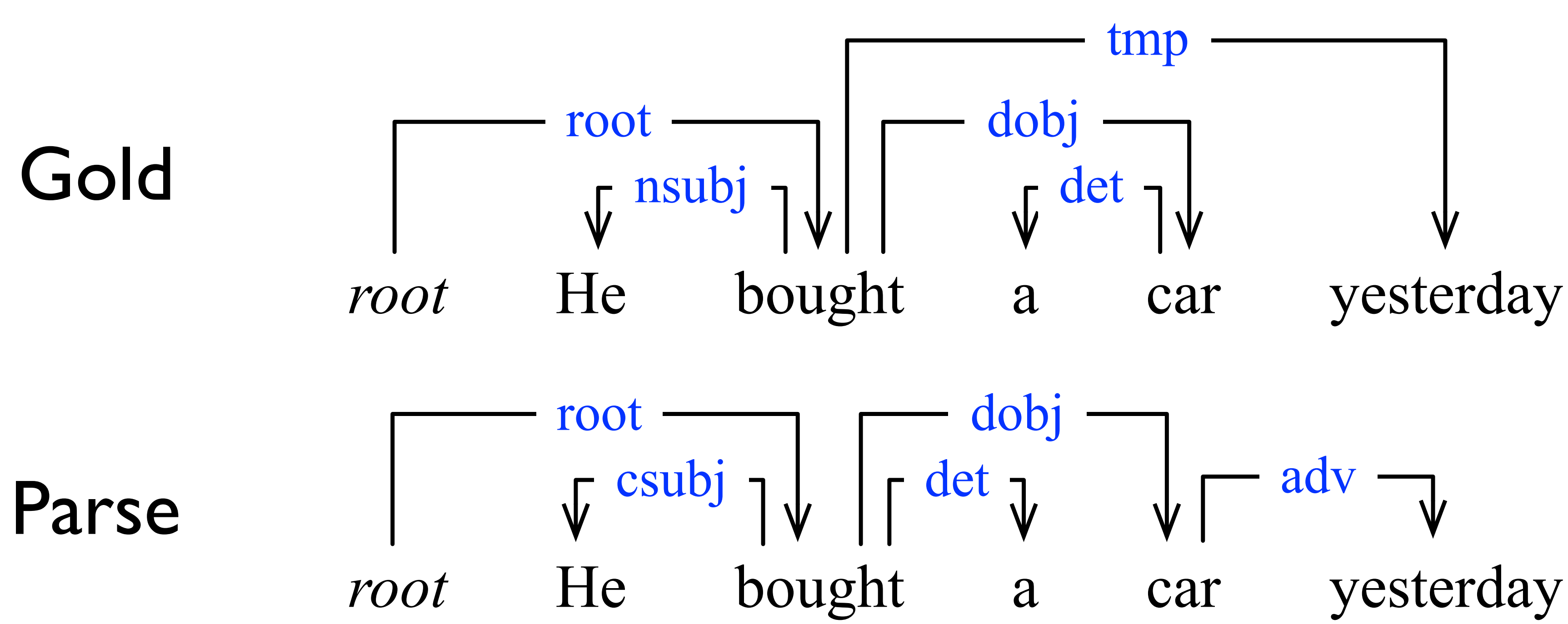
Assume each node has exactly one head except for the *root*.

Unlabeled attachment score

How many nodes found correct heads.

Labeled attachment score

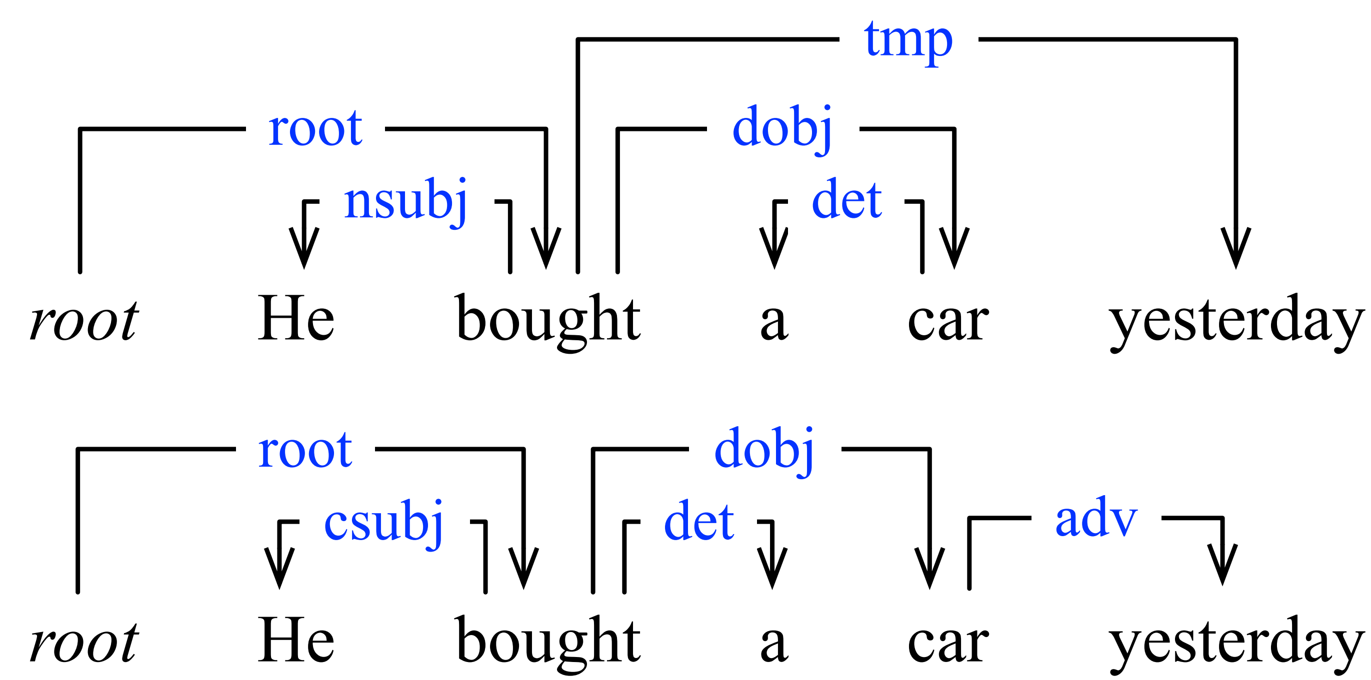
How many nodes found correct heads and labels.



Attachment Scores

Gold

Parse



Unlabeled attachment score

(He, bought)
(bought, *root*)
(a, bought)
(car, bought)
(yesterday, car)

= 3/5

Labeled attachment score

(He, bought, csubj)
(bought, *root*, root)
(a, bought, det),
(car, bought, dobj)
(yesterday, car, adv)

= 2/5

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Transition-based Parsing

- Nivre's arc-eager algorithm
  - Projective parsing algorithm with a worst-case complexity of O(n).
  - S = stack, I = list of input tokens, A = set of arcs.

Initialization	$\langle \mathbf{nil}, W, \emptyset \rangle$	
Termination	$\langle S, \mathbf{nil}, A \rangle$	
Left-Reduce	$\langle w_j w_i \mid S, I, A \rangle \rightarrow \langle w_j \mid S, I, A \cup \{(w_j, w_i)\} \rangle$	$\neg \exists w_k (w_k, w_i) \in A$
Right-Reduce	$\langle w_j w_i \mid S, I, A \rangle \rightarrow \langle w_i \mid S, I, A \cup \{(w_i, w_j)\} \rangle$	$\neg \exists w_k (w_k, w_j) \in A$
Shift	$\langle S, w_i \mid I, A \rangle \rightarrow \langle w_i \mid S, I, A \rangle$	

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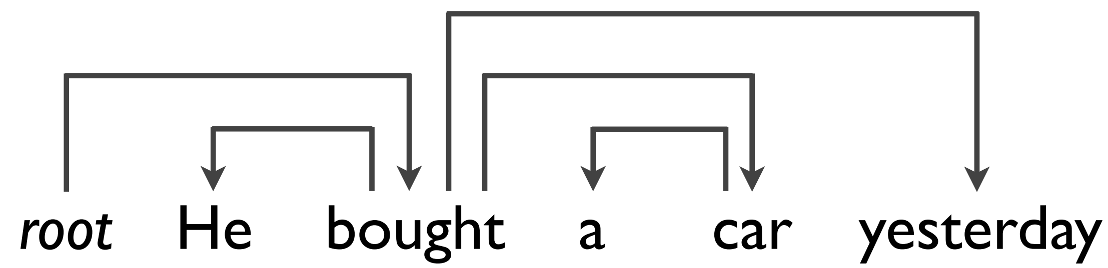


root

S

He
bought
a
car
yesterday

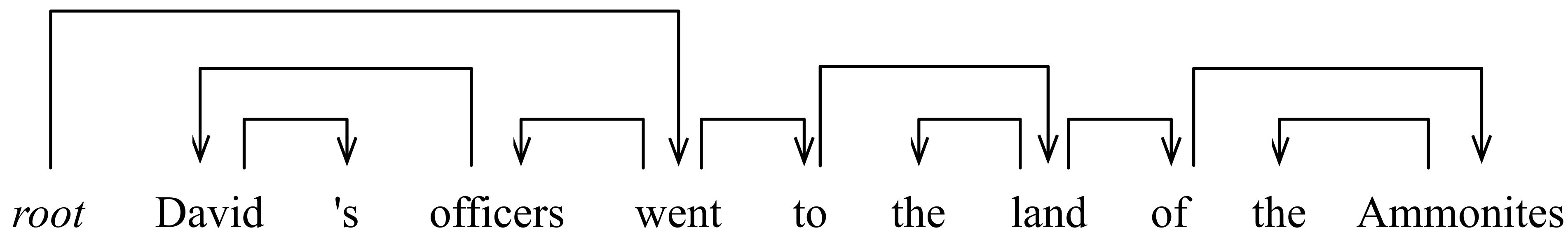
I

bought → yes..
bought → car
a ← car
root → bought
He ← bought

A

- Shift : ‘He’
- LeftArc : ‘He’ ← ‘bought’
- RightArc: *root* → ‘bought’
- Shift : ‘a’
- LeftArc : ‘a’ ← ‘car’
- RightArc: ‘bought’ → ‘car’
- Reduce: ‘car’
- RightArc: ‘bought’ → ‘yesterday’

Nivre's Arc-eager Algorithm



Initialization	$\langle \mathbf{nil}, W, \emptyset \rangle$	
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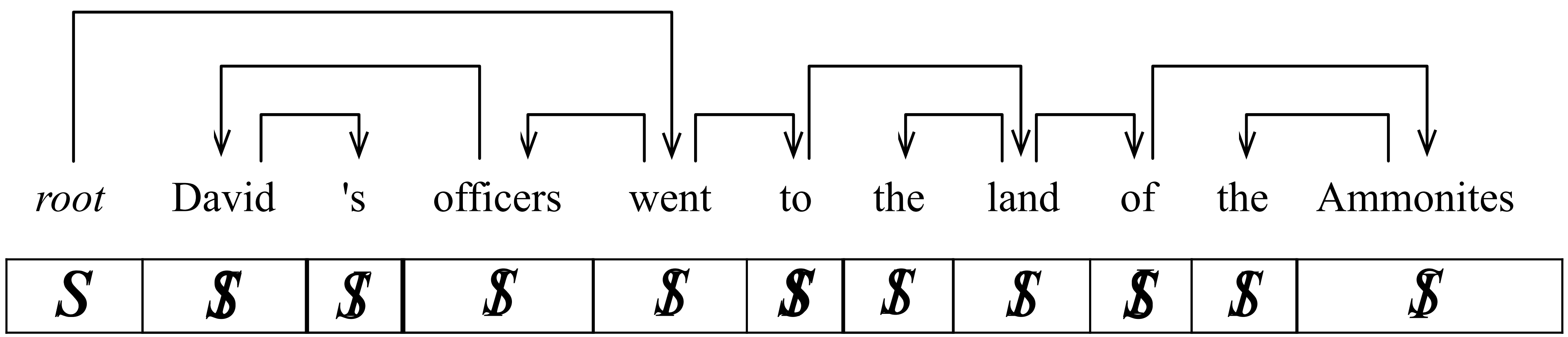
Nivre's Arc-eager Algorithm



- Initialize
- Shift: 'David'
- Right-Arc: David → 's
- Reduce: 's
- Left-Arc: David ← 'officers'
- Shift: officers
- Left-Arc: officers ← went
- Right-Arc: *root* → went
- Right-Arc: went → to
- Shift: the
- Left-Arc: the ← land
- Right-Arc: to → land
- Right-Arc: land → of
- Shift: 'the'
- Left-Arc: the ← Ammonites
- Right-Arc: of → Ammonites
- Terminate