Dependency Grammar

COMP90042

Natural Language Processing

Lecture 16

Semester 1 2022 Week 8

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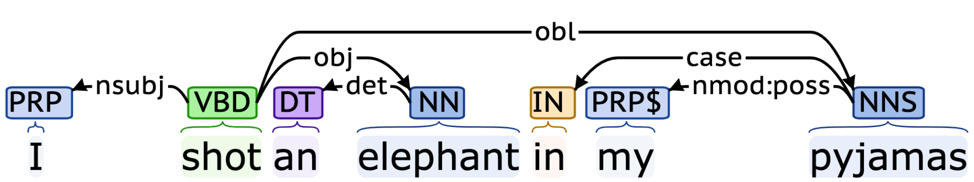
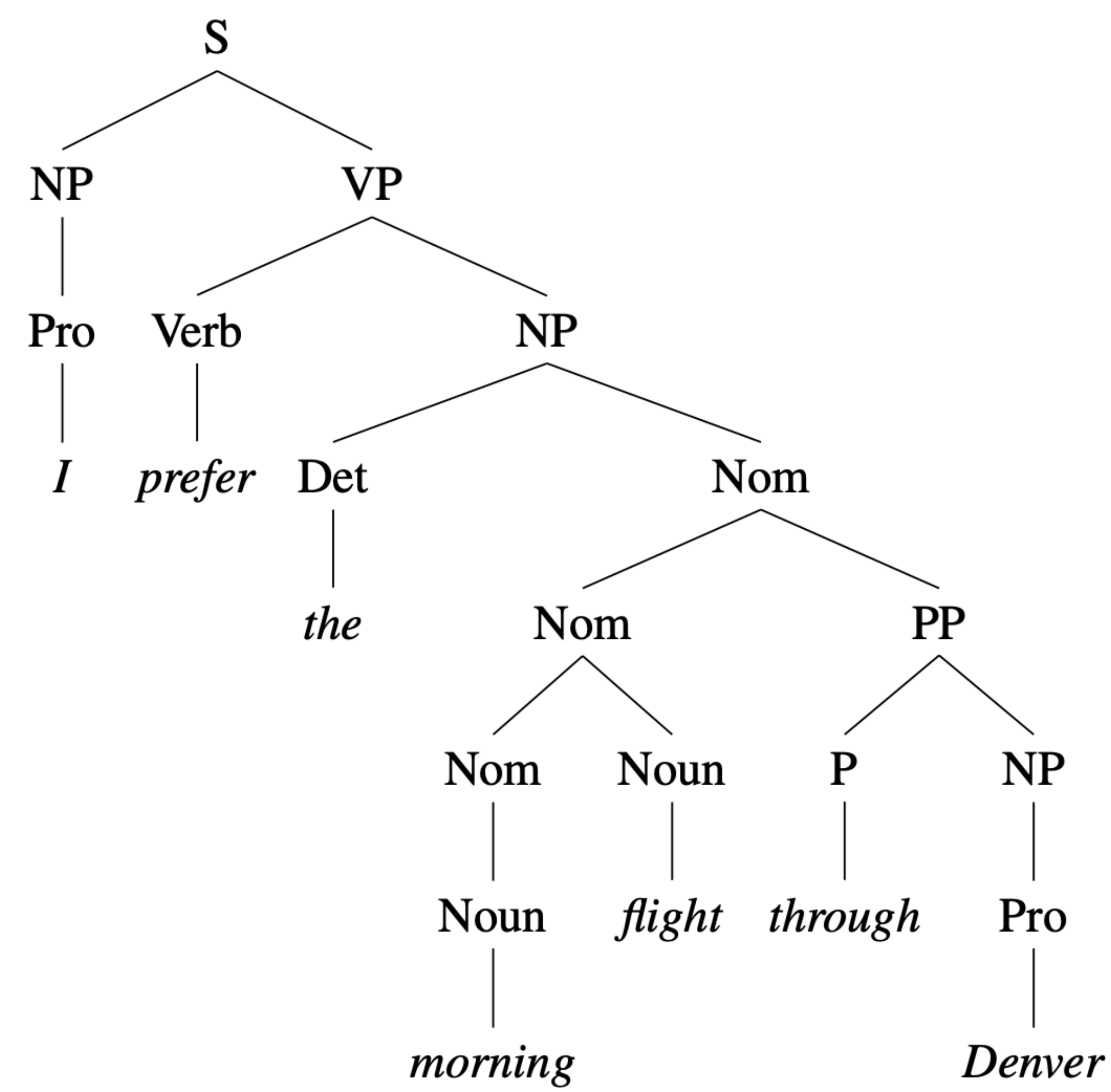


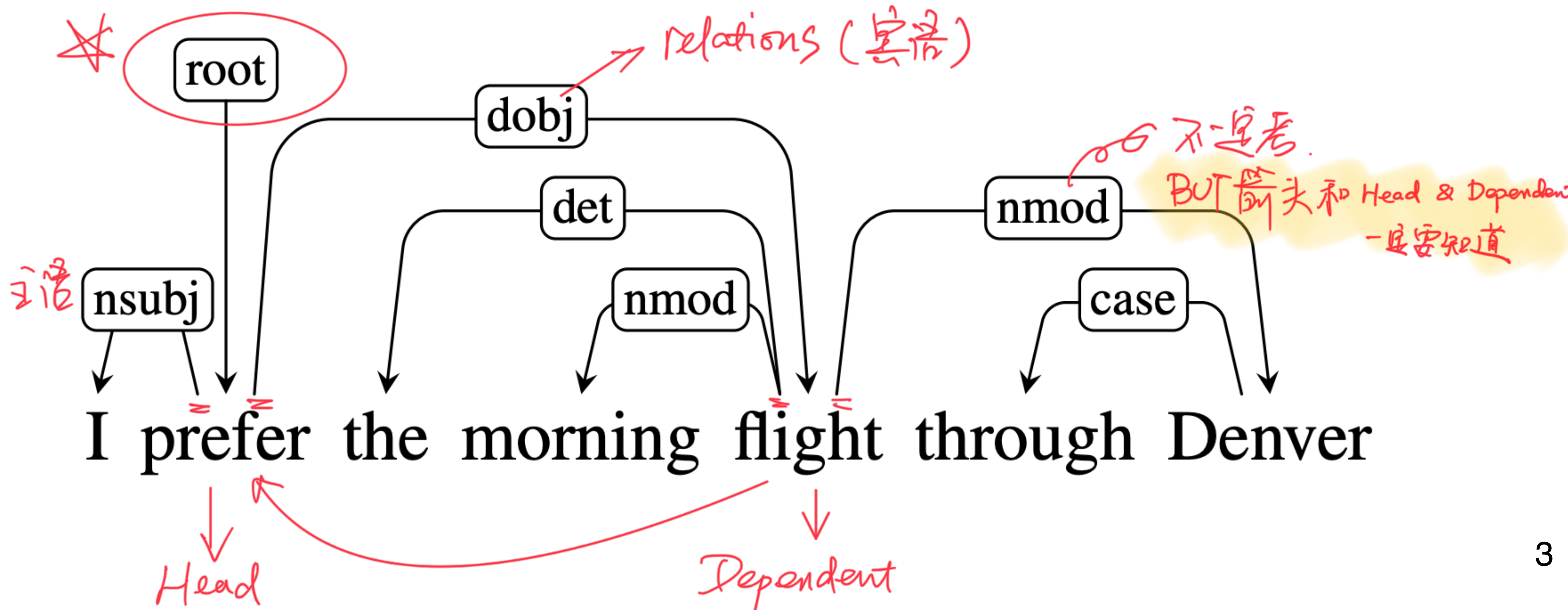
Context-Free Grammars (Recap)

- CFGs assume a constituency tree which identifies the **phrases** in a sentence
  - based on idea that these phrases are interchangeable (e.g., swap an NP for another NP) and maintain grammaticality



Dependency Grammars

- Dependency grammar offers a simpler approach
  - describe **relations** between pairs of words
  - namely, between **heads** and **dependents**
  - e.g. (*prefer*, dobj, *flight*)



Why?

- Deal better with languages that are morphologically rich and have a relatively free word order
    - CFG need a separate rule for each possible place a phrase can occur in
- Head-dependent relations similar to semantic relations between words
    - More useful for applications: coreference resolution, information extraction, etc

Outline

- Basics of dependency grammar
- Transition-based parsing
- Graph-based parsing

Basics of Dependency Grammar

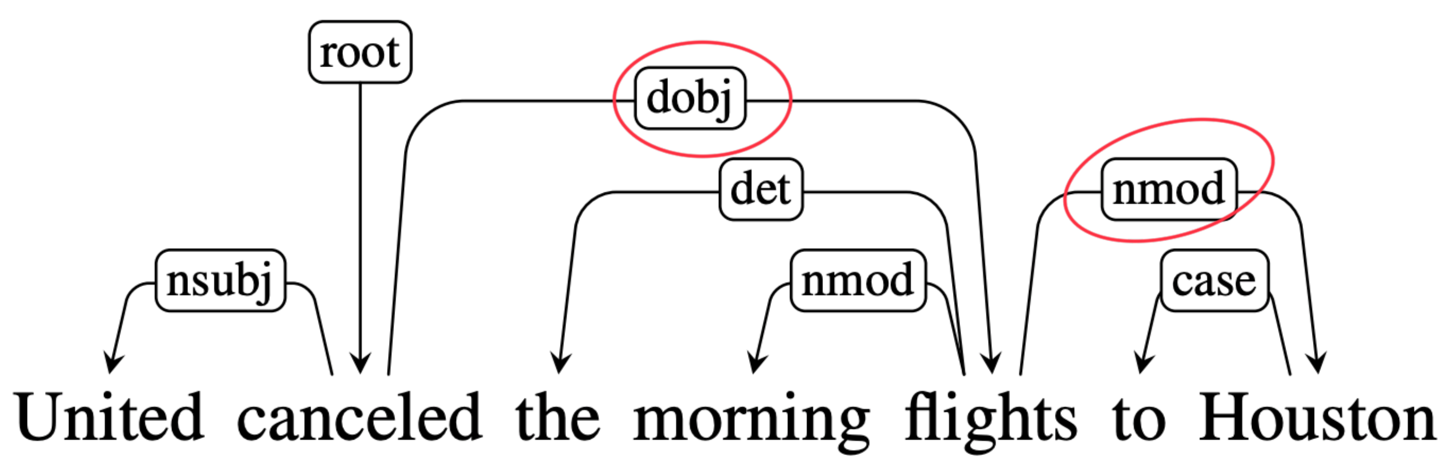
Dependency Relations

- Captures the grammatical relation between:
  - **Head** = central word
  - **Dependent** = supporting word
- Grammatical relation = subject, direct object, etc
- Many dependency theories and taxonomies proposed for different languages
- **Universal Dependency**: a framework to create a set of dependency relations that are computationally useful and **cross-lingual**

label信息

Universal Dependency

Clausal Argument Relations	Description
NSUBJ	Nominal subject
DOBJ	Direct object
IOBJ	Indirect object
CCOMP	Clausal complement
XCOMP	Open clausal complement
Nominal Modifier Relations	**Description**
NMOD	Nominal modifier
AMOD	Adjectival modifier
NUMMOD	Numeric modifier
APPOS	Appositional modifier
DET	Determiner
CASE	Prepositions, postpositions and other case markers
Other Notable Relations	**Description**
CONJ	Conjunct
CC	Coordinating conjunction

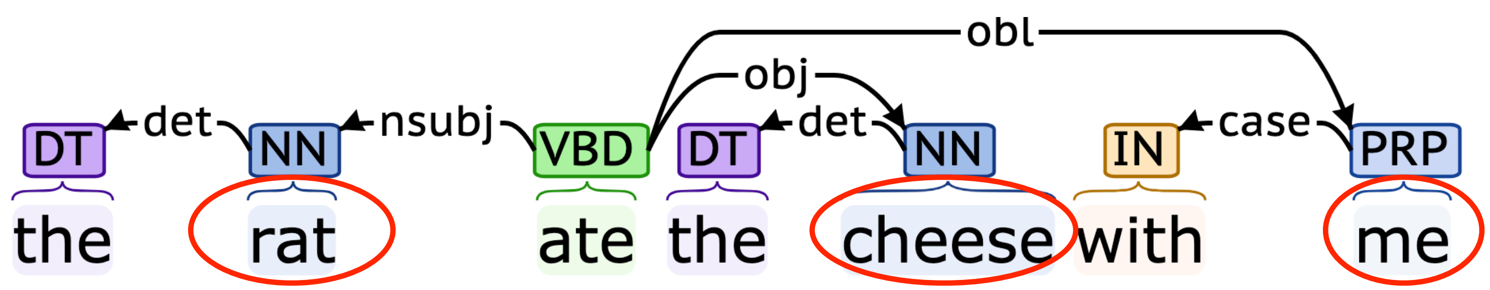


More Examples

Relation	Examples with *head* and **dependent**
NSUBJ	**United** *canceled* the flight.
DOBJ	United *diverted* the **flight** to Reno.
	We *booked* her the first **flight** to Miami.
IOBJ	We *booked* **her** the flight to Miami.
NMOD	We took the **morning** *flight*.
AMOD	Book the **cheapest** *flight*.
NUMMOD	Before the storm JetBlue canceled **1000** *flights*.
APPOS	*United*, a **unit** of UAL, matched the fares.
DET	**The** *flight* was canceled.
	Which *flight* was delayed?
CONJ	We *flew* to Denver and **drove** to Steamboat.
CC	We flew to Denver **and** *drove* to Steamboat.
CASE	Book the flight **through** *Houston*.

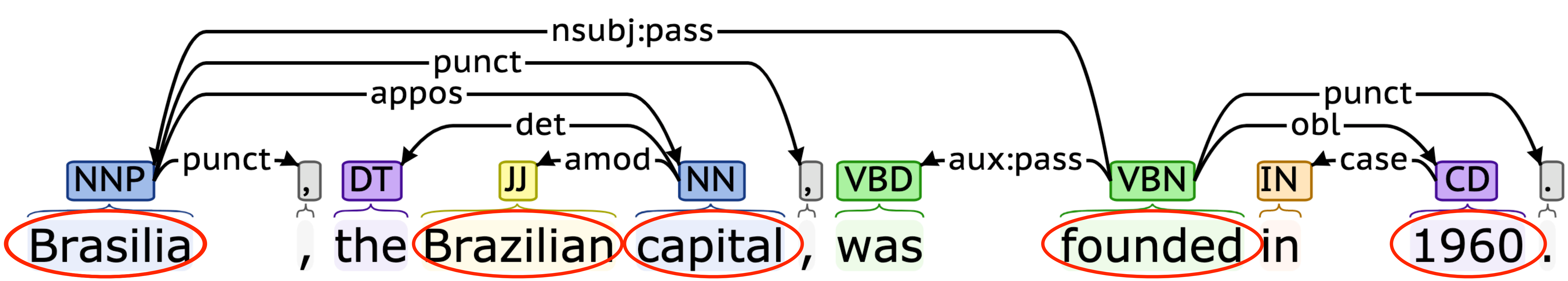
Question Answering

- Dependency tree more directly represents the core of the sentence: **who did what to whom?**
  - captured by the links incident on verb nodes



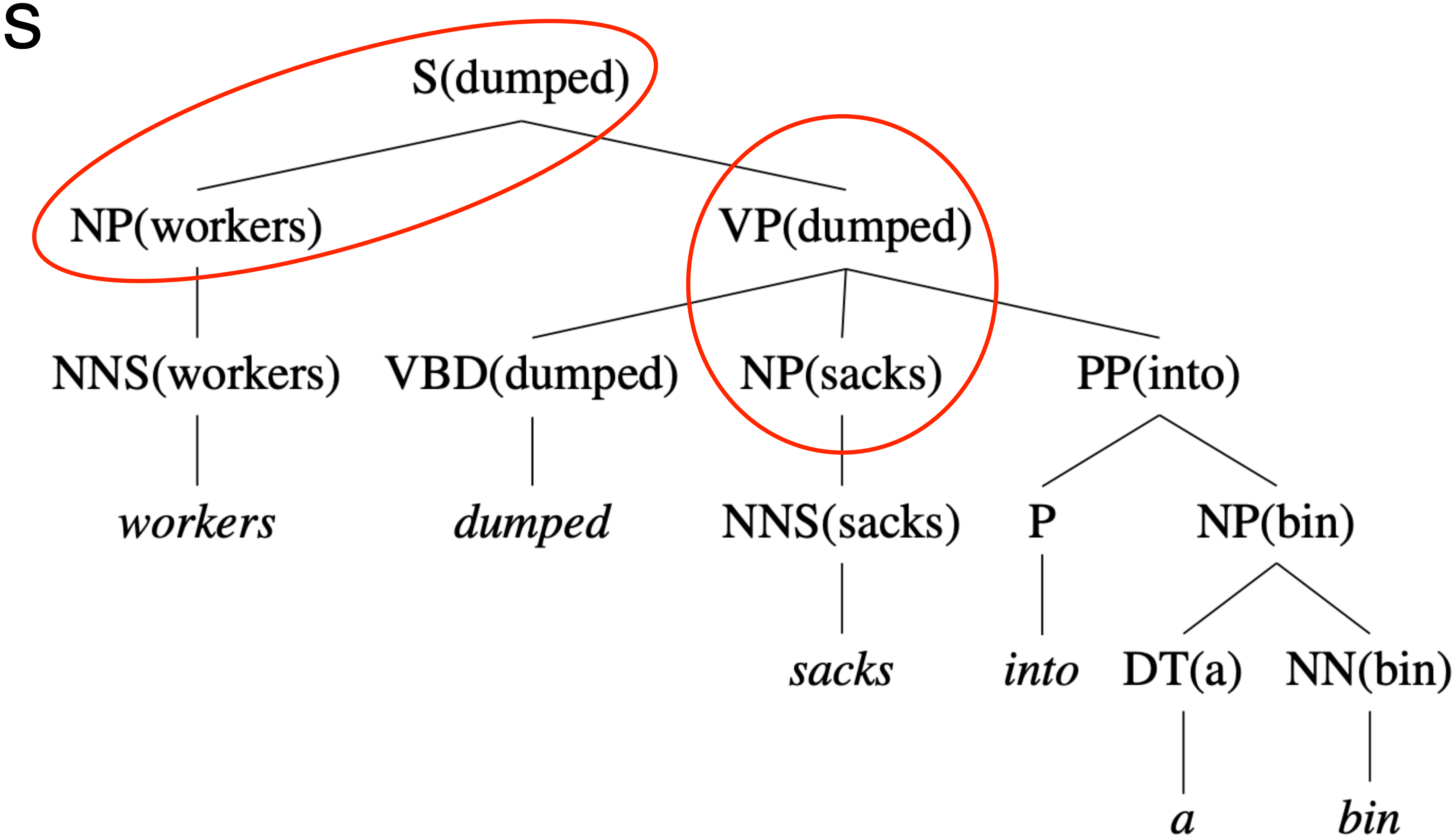
Information Extraction

- “Brasilia, the Brazilian capital, was founded in 1960.”
  - → capital(Brazil, Brasilia)
  - → founded(Brasilia, 1960)
- Dependency tree captures relations succinctly



What about CFGs

- Constituency trees can also provide similar information
- But it requires some distilling using head-finding rules



Dependency vs Constituency

Workshop 9

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- ? Dependency tree
  - each node is a word token
  - one node is chosen as the root
  - directed edges link heads and their dependents
- ? Constituency tree
  - forms a hierarchical tree
  - word tokens are the leaves
  - internal nodes are 'constituent phrases' e.g. NP
- Both use part-of-speech

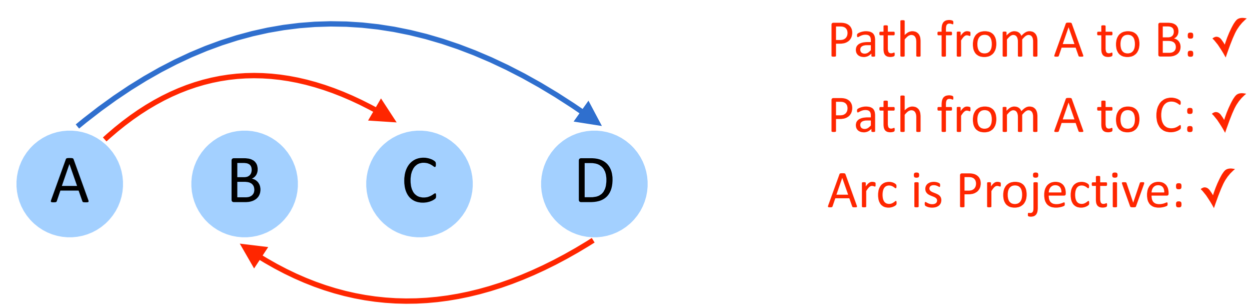
共同点

Properties of a Dependency Tree

- Each word has a single head (parent)
- There is a single root node
- There is a unique path to each word from the root
- All arcs should be **projective**

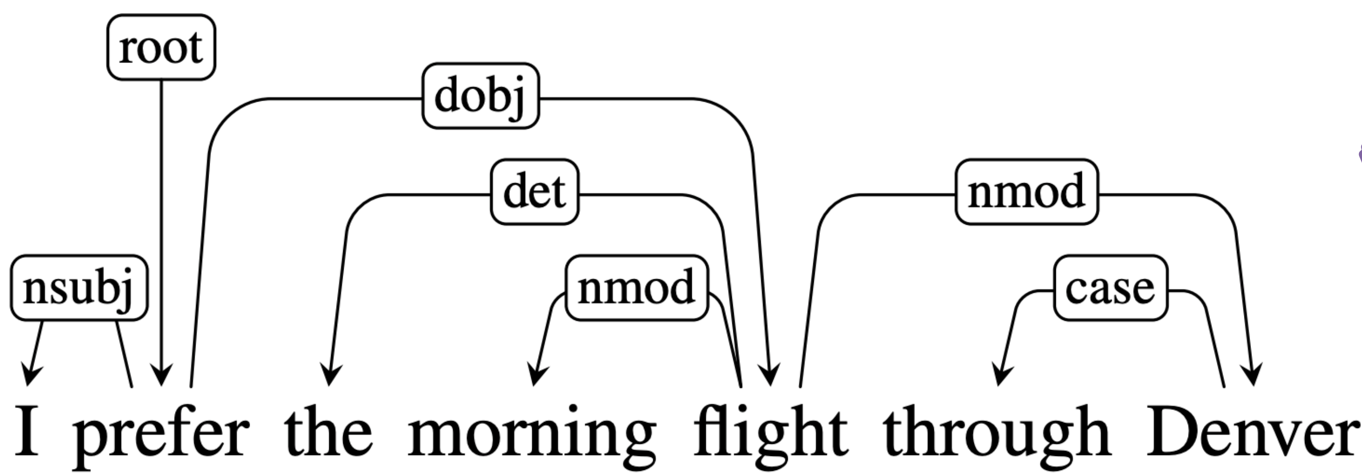
Projectivity

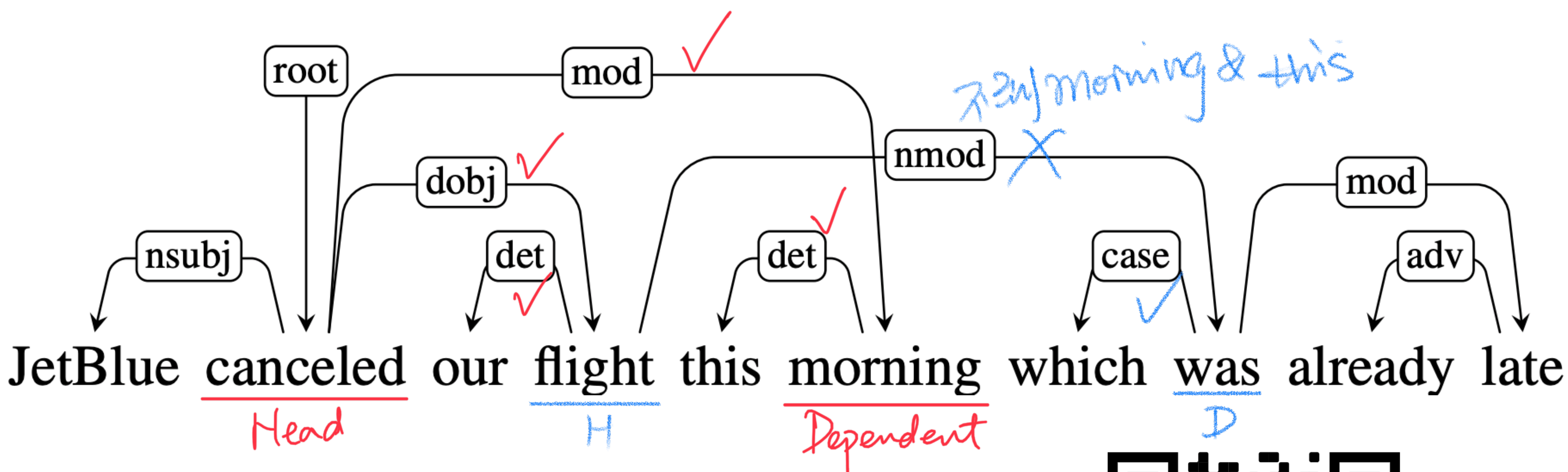
- An arc is projective if there is a path from head to every word that lies between the head and the dependent



- Dependency tree is projective if all arcs are projective
- In other words, a dependency tree is projective if it can be drawn with no **crossing edges**
- Most sentences are projective, but exceptions exist
  - Common in languages with flexible word order

Projectivity





Is this tree projective?

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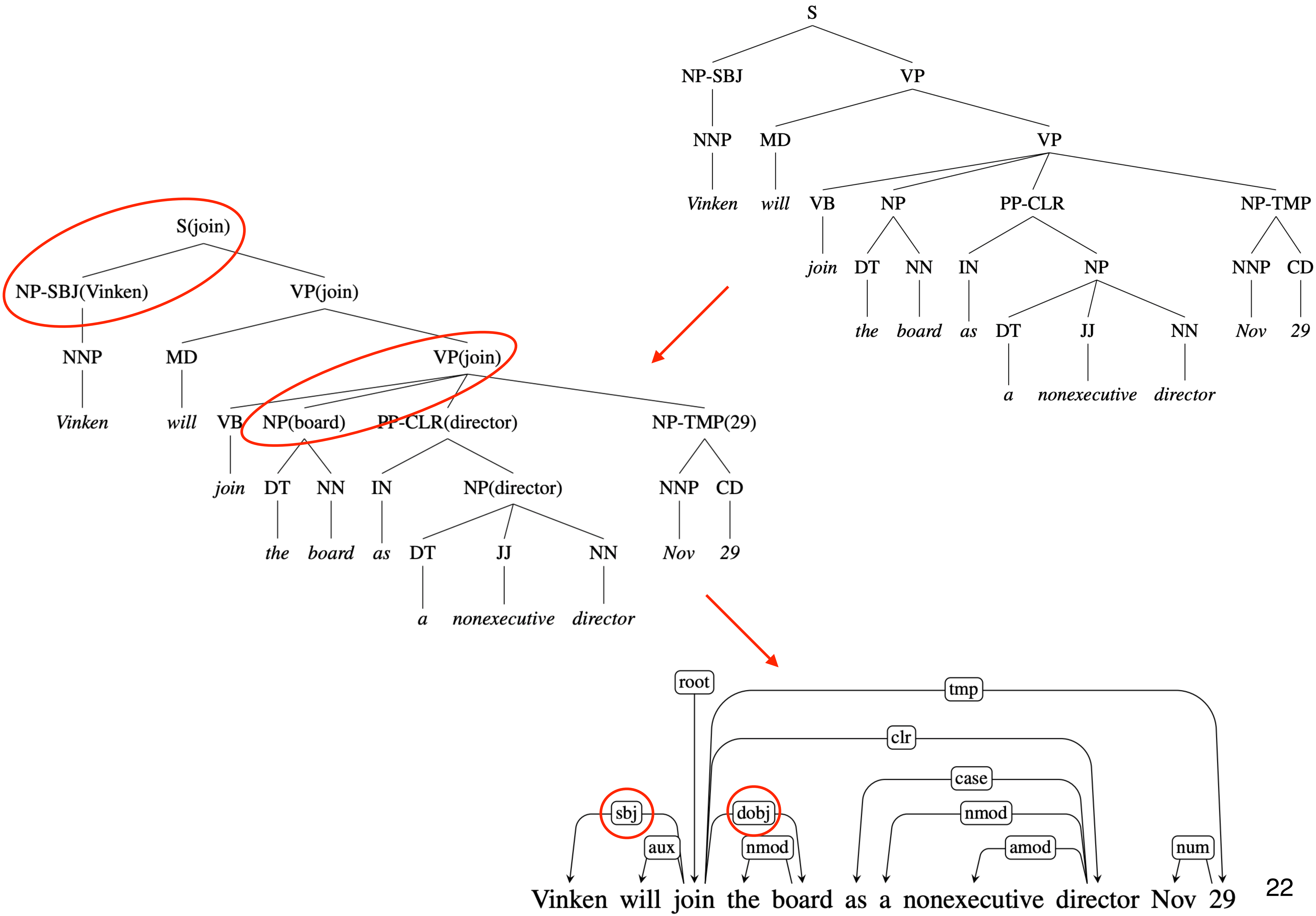
Treebank Conversion

- A few dependency treebanks (Czech, Arabic, Danish…)
- Many constituency treebanks
- Some can be converted into dependencies
- Dependency trees generated from constituency trees are **always projective**
- Main idea: identify head-dependent relations in constituency structure and the corresponding dependency relations
  - Use various heuristics, e.g., head-finding rules
  - Often with manual correction


S
NP-SBJ
VP
NNP
MD
VP
Vinken
will
VB
NP
PP-CLR
NP-TMP
join
DT
NN
IN
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CD
the
board
as
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JJ
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Nov
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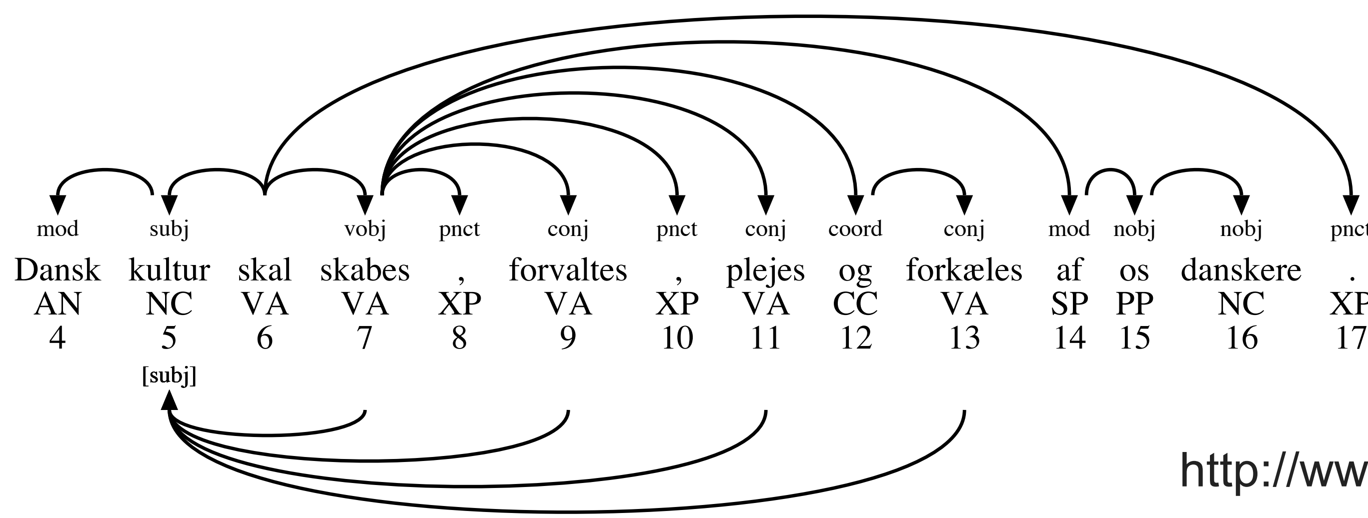
a
nonexecutive
director
S(join)
NP-SBJ(Vinken)
VP(join)
NNP
MD
VP(join)
Vinken
will
VB
NP(board)
PP-CLR(director)
NP-TMP(29)
join
DT
NN
IN
NP(director)
NNP
CD
the
board
as
DT
JJ
NN
Nov
29
a
nonexecutive
director
root
tmp
clr
case
sbj
dobj
nmod
aux
nmod
amod
num
Vinken will join the board as a nonexecutive director Nov 29

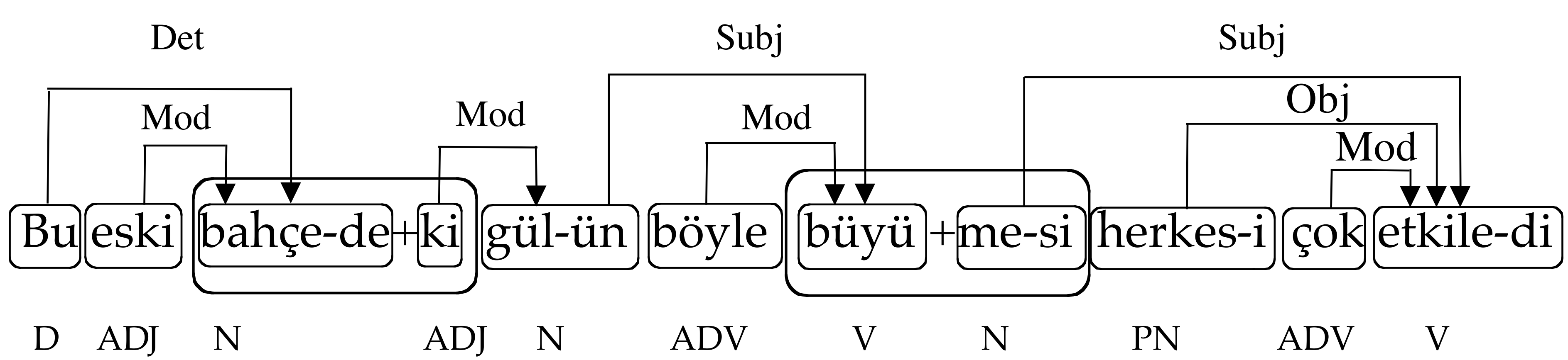
Examples From Treebanks

- Danish DDT includes additional 'subject' link for verbs



http://www.buch-kromann.dk/matthias/ddt1.0/

- METU-Sabancı Turkish treebank
  - edges between morphological units, not just words



Oflazer, Kemal, et al. "Building a Turkish treebank." *Treebanks*. Springer, 2003. 261-277.

Transition-based Parsing

Dependency Parsing

- Find the best structure for a given input sentence
- Two main approaches:
  - **Transition-based**: bottom-up greedy method
  - **Graph-based**: encodes problem using nodes/ edges and use graph theory methods to find optimal solutions

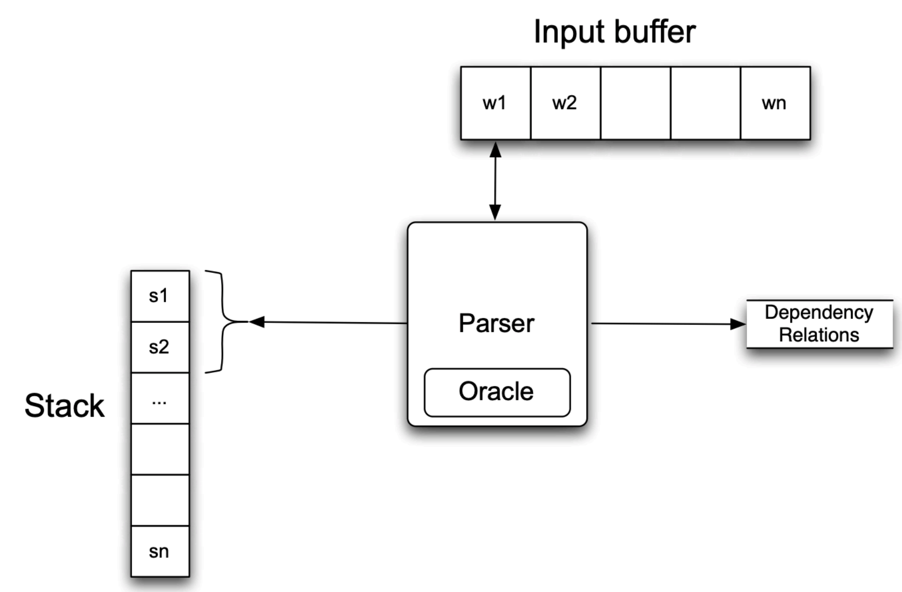
Caveat (Warning)

- Transition-based parsers can only handle **projective** dependency trees!
- Less applicable for languages where cross-dependencies are common

应用很广泛，但无法应用到cross-dependencies很common的情况.
大多数语言是projective的.

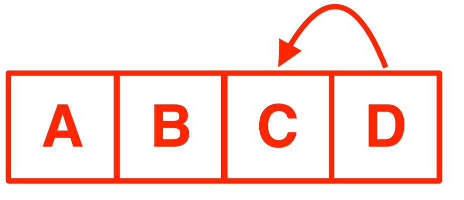
Transition-Based Parsing: Intuition

- Processes word from left to right
- Maintain two data structures
  - **Buffer**: input words yet to be processed 要处理.
  - **Stack**: store words that are being processed 处理后.

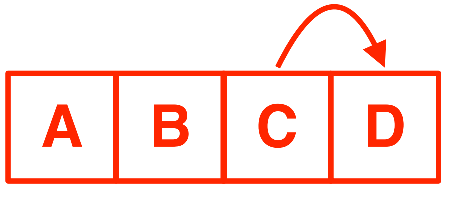


Transition-Based Parsing: Intuition

- At each step, perform one of the 3 actions:
  1. ▸ **Shift:** move a word from buffer to stack
  2. ▸ **Left-Arc:** assign current word as head of the previous word in stack

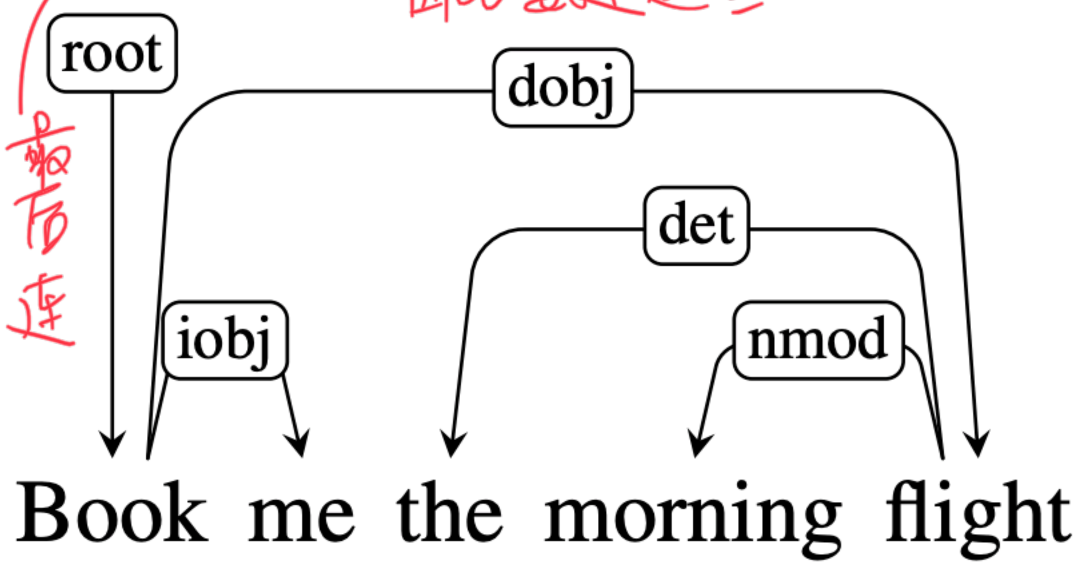


  3. ▸ **Right-Arc:** assign previous word as head of current word in stack



因为要连这些

最后连



要考！！！

只用了一次，连 ✓
被book吃掉

Step	Stack	Buffer	Action	Relation Added
0	[root]	[book, me, the, morning, flight]	SHIFT	
1	[root, book]	[me, the, morning, flight]	SHIFT	
2	[root, book, me]	[the, morning, flight]	RIGHTARC	(book → me)
3	[root, book]	[the, morning, flight]	SHIFT	
4	[root, book, the]	[morning, flight]	SHIFT	
5	[root, book, the, morning]	[flight]	SHIFT	
6	[root, book, the, morning, flight]	[]	LEFTARC	(morning ← flight)
7	[root, book, the, flight]	[]	LEFTARC	(the ← flight)
8	[root, book, flight]	[]	?	?
9	[root, book]	[]	RightArc	book → flight
10	[root]		RightArc	root → book
			Done	

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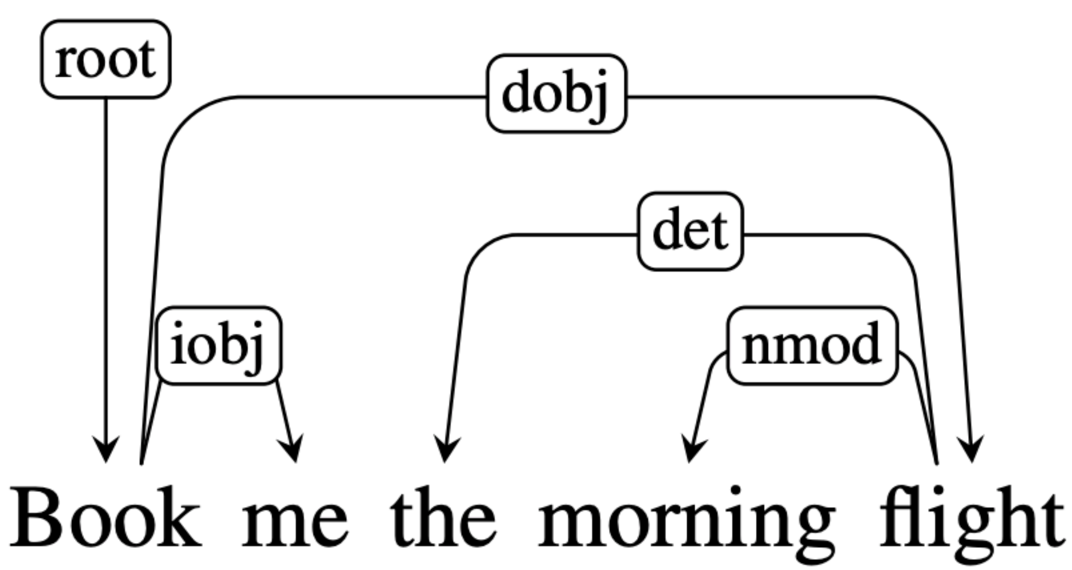
Dependency Labels

- For simplicity, we omit labels on the dependency relations
- In practice, we parameterise the left-arc and right-arc actions with dependency labels:
  - E.g. left-arc-nsubj or right-arc-dobj
- Expands the list of actions to > 3 types

The Right Action?

- We assume an **oracle** that tells us the right action at every step
- Given a dependency tree, the role of oracle is to generate a sequence of ground truth actions



Action
SHIFT
SHIFT
RIGHTARC
SHIFT
SHIFT
SHIFT
LEFTARC
LEFTARC
RIGHTARC
RIGHTARC
Done

Parsing Model

- We then train a supervised model to **mimic** the actions of the oracle
  - To learn at every step the correct action to take (as given by the oracle)
  - At test time, the trained model can be used to parse a sentence to create the dependency tree

Parsing As Classification

- Input:
  - Stack (top-2 elements: s_1 and s_2)
  - Buffer (first element: b_1)
- Output
  - 3 classes: *shift*, *left-arc*, or, *right-arc*
- Features
  - word (w), part-of-speech (t)

Stack	Word buffer	Relations
[root, canceled, flights]	[to Houston]	(canceled $\rightarrow$ United) (flights $\rightarrow$ morning) (flights $\rightarrow$ the)

- Input features:
  - $s_1.w$ = *flights*
  - $s_2.w$ = *cancelled*
  - $s_1.t$ = *NNS*
  - $s_2.t$ = *VBD*
  - $b_1.w$ = *to*
  - $b_1.t$ = *TO*
  - $s_1.t \circ s_2.t$ = *NNS_VBD*
- Output label: *shift*

Source	Feature templates		
One word	$s_1.w$	$s_1.t$	$s_1.wt$
	$s_2.w$	$s_2.t$	$s_2.wt$
	$b_1.w$	$b_1.w$	$b_0.wt$
Two word	$s_1.w \circ s_2.w$	$s_1.t \circ s_2.t$	$s_1.t \circ b_1.w$
	$s_1.t \circ s_2.wt$	$s_1.w \circ s_2.w \circ s_2.t$	$s_1.w \circ s_1.t \circ s_2.t$
	$s_1.w \circ s_1.t \circ s_2.t$	$s_1.w \circ s_1.t$	

Classifiers

- Traditionally SVM works best
- Nowadays, deep learning models are state-of-the-art
- Weakness: local classifier based on greedy search
- Solutions:
  - Beam search: keep track of top-N best actions
  - Dynamic oracle: during training, use predicted actions occasionally
  - Graph-based parser

Graph-based Parsing

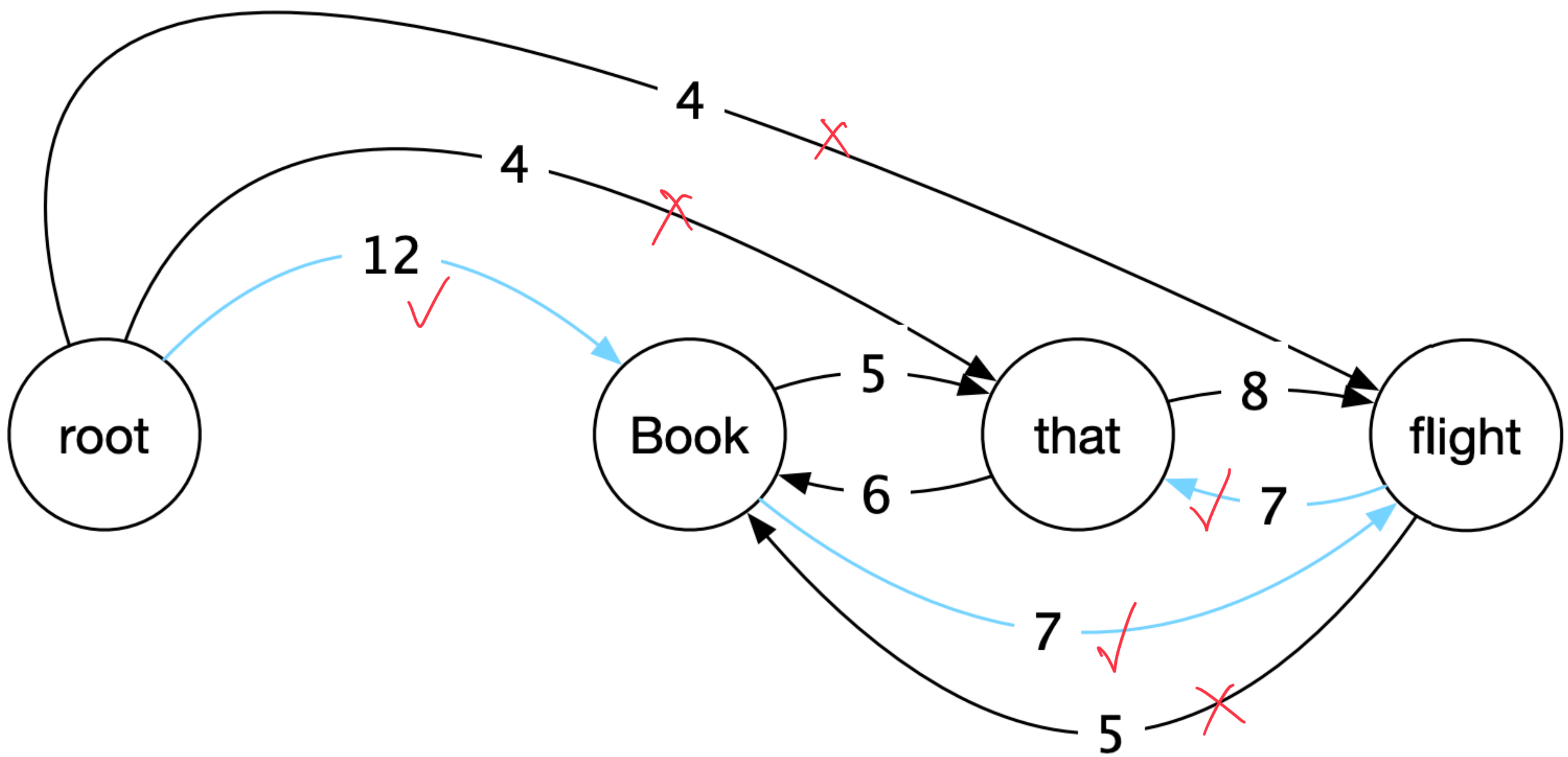
Graph-Based Parsing

- Given an input sentence, construct a fully-connected, weighted, directed graph
- **Vertices**: all words
- **Edges**: head-dependent arcs
- **Weight**: score based on training data (relation that is frequently observed receive a higher score)
- **Objective**: find the maximum spanning tree (Kruskal's algorithm)

Advantage

- Can produce non-projective trees
  - Not a big deal for English
  - But important for many other languages
- Score entire trees
  - Avoid making greedy local decisions like transition-based parsers
  - Captures long dependencies better

Example



- Caveat: tree may contain cycles
- Solution: need to do cleanup to remove cycles (Chu-Liu-Edmonds algorithm)

A Final Word

- Dependency parsing a compelling, alterative, formulation to constituency parsing
  - Edges encode word-word syntactic and semantic relations
- Transition-based parsing
- Graph-based parsing

Required Reading

- JM3 Ch. 14