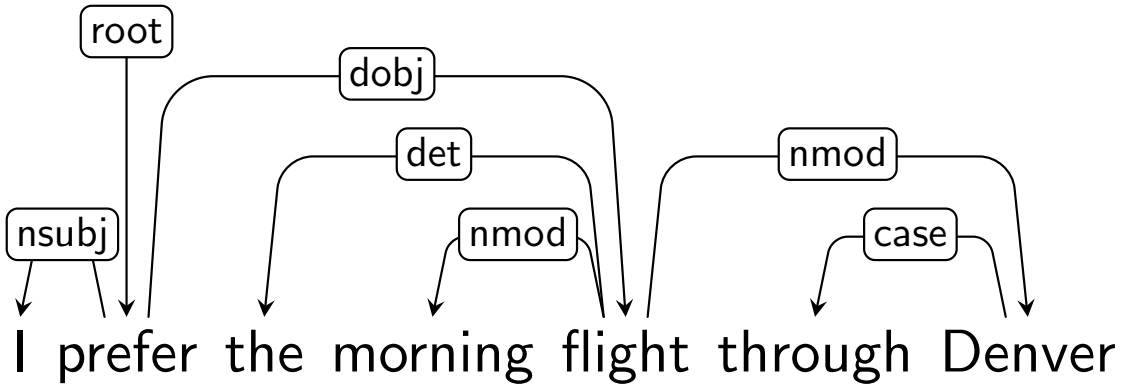
Dependency Grammars: Avoiding Constituents

- Traditional way of thinking
  - Goes back to Panini (Pāṇini circa 350BC)
  - Modern form: Lucien Tesnière, 1950s
- *Typed dependency structure*: Captures grammatical relations directly between words



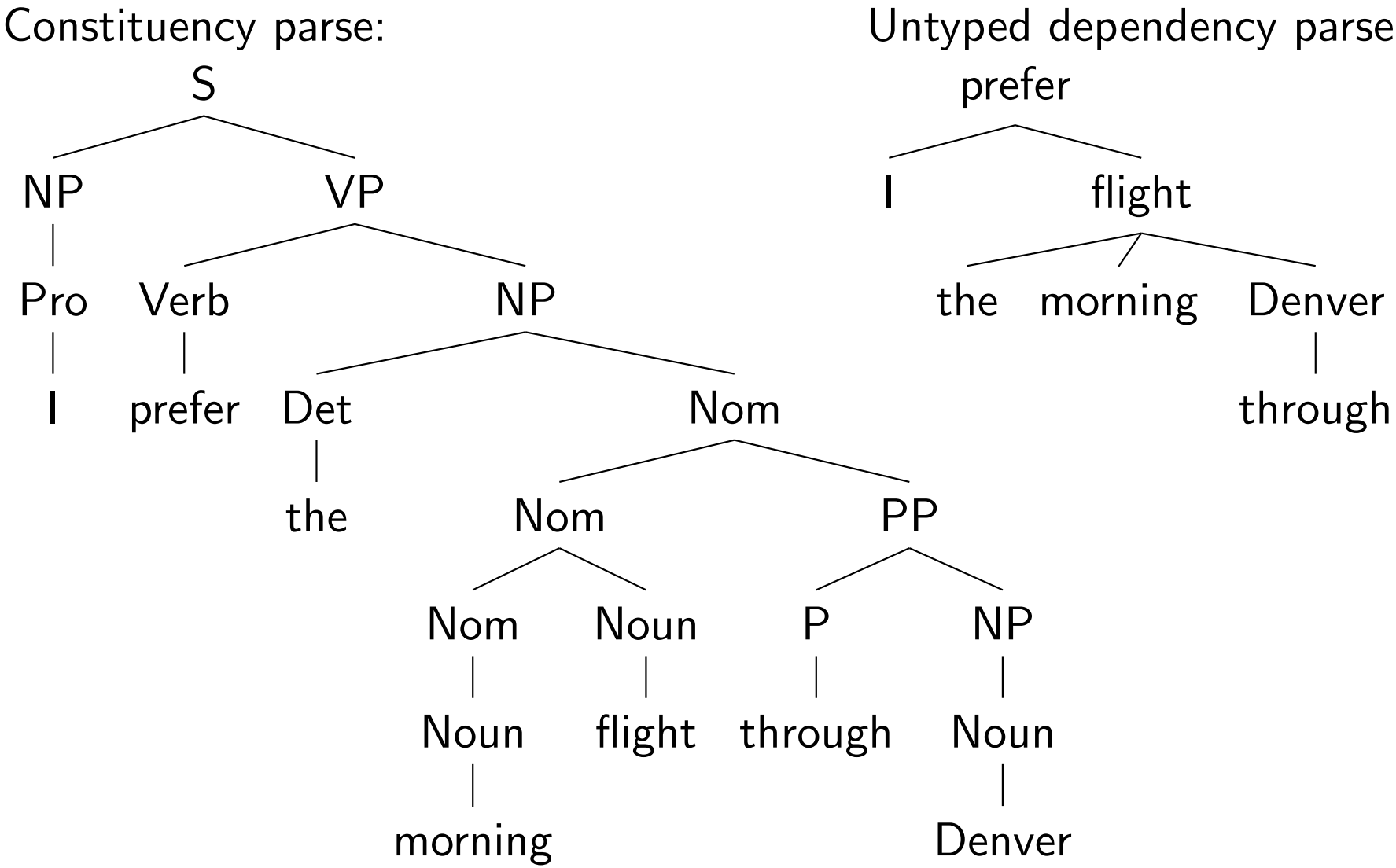
- Well-suited for languages that have free word order

Free Word Order Languages

"Free" means somewhat free

- Convey information about types through richer morphemes
- CFGs focus on structure and word order
  - Lead to large grammars to handle allowed orders
  - Produce large structures
  - Relationships between words that relevant for understanding the meaning can be several edges away in a parse tree
- Dependency representations
  - Can express the elements of the structure essential for meaning
  - Bring forth the head word for each phrase and the relations in reference to the head word

Constituency versus (Untyped) Dependency Parses



Constituency versus (Untyped) Dependency Parses

What are some tradeoffs?

Constituency versus (Untyped) Dependency Parses

What are some tradeoffs?

- Constituency parses
  - Preserve word order
  - More information on structure
- Dependency parses
  - Lose word order
  - More *functional*: parent "applies" on children

Case and Thematic Roles

- Case (more syntactic): A grammatical relation with respect to a verb
- Thematic Role (more semantic): An "argument" assigned by a verb
- Essential to understanding the meaning of a sentence
- Panini's *karaka*
- Latin has cases indicated by *declensions*
- Fillmore's case grammar $\sim$ 1960s
- Example thematic roles
  - Agent: intentional doer
  - Experiencer: one who undergoes a (change in a) state of being
  - Theme or Patient: receiver of an action
  - Instrument
  - Goal or Telos: where the action takes us
  - Location: where the action occurs
  - Source: from where
  - Benefactive: from whom
  - Cause or point of departure

Excerpted from Churchill's Memoir

Churchill was told to memorize this table about tables (first two columns)

Mensa	a table	Nominative	The table is solid
Mensa	O table	Vocative	Fold up, table!
Mensam	a table	Accusative	Scratched the table
Mensae	of a table	Genitive	The top of the table
Mensae	to or for a table	Dative	Give the table a wash
Mensa	by, with, or from a table	Ablative	Fell off the table

"Mensa, O table, is the vocative case," he replied

"But why O table?" I persisted in genuine curiosity

"O table – you would use that in addressing a table, in invoking a table"

And then seeing he was not carrying me with him,

"You would use it in speaking to a table"

"But I never do," I blurted out in honest amazement

"If you are impertinent, you will be punished, and punished, let me tell you, very severely," was his conclusive rejoinder

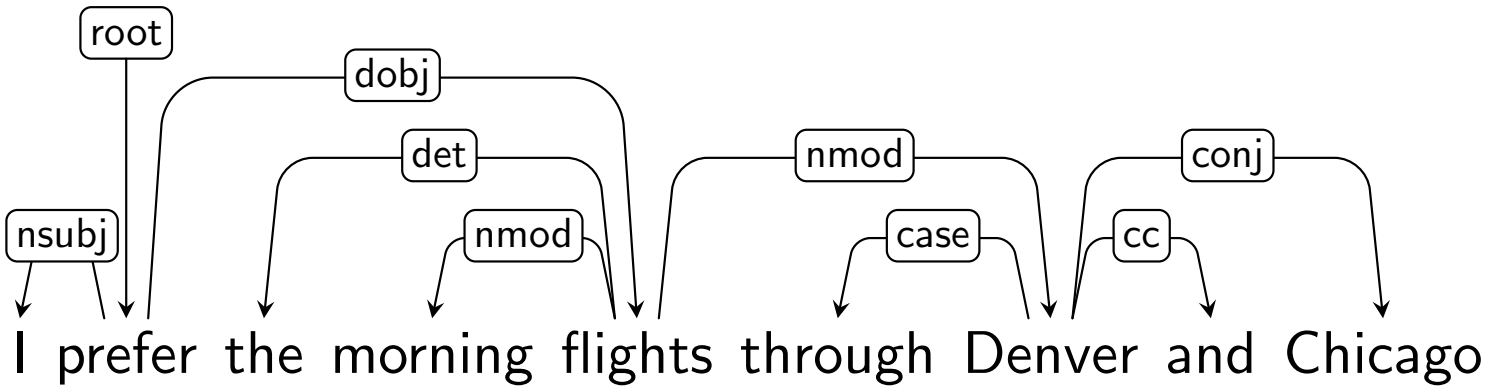
When would someone address a table?

Universal Dependencies Project

Joakim Nivre and others

- Identify relations that are
  - Linguistically justified
  - Occur in multiple languages
  - Potentially usable for NLP
- Clausal relations
  - Capture syntactic roles with respect to a verb
- Modifier relations
  - How a word modifies its head
- Coordinating conjunctions
  - An arbitrary or corpus-specific choice as to head and dependent
  - An EMT and a police officer revived the victim: EMT or officer as head?

Exercise: Clausal, Modifier, or Coordinating Relation



Head versus Dependent

Kübler, McDonald, and Nivre 2009

Criteria for identifying a head H and a dependent D in a linguistic "construction" (e.g., constituent) C

- H determines the syntactic category of C and can often replace C
  - This would be an *endocentric* construction
- H determines the semantic category of C; D gives semantic specification
- H is mandatory; D may be optional
- H selects D and determines whether D is mandatory or optional
  - Optional (here, an adjective): Dan likes sugared water
  - Mandatory (here, a determiner): Ayaan ate a/the/one/Ian's pear
- The form of D depends on H (agreement or government)
  - He (*him) helped Maya versus Suma helped him (*he)
  - Where are the bananas (*banana)
- The linear position of D is specified in relation to H (before in English)

Endocentric versus Exocentric

- Endocentric
  - Support substitution of an entire construct by its head
  - Typically, head-modifier relations
  - Adjective, adverb, nominal modifier, . . .
- Exocentric
  - Do not support substitution of an entire construct by its head
  - Typically, head-complement relations
  - Subject, object, copula, . . .
    - NB: Copula is a linking word rooted in *be*

      The marker is green

Determining Head-Dependent Relations can be Tricky

Joakim Nivre's example

I can see that they rely on this and that .

- Complex verb groups
  - Auxiliary and main verb "can see"
- Subordinate clauses
  - Complementizer and verb "see that ... "
- Coordination
  - Coordination and conjuncts "this and that"
- Prepositional phrases
  - Preposition and nominal "on (this and that)"
- Punctuation
  - Link to the verb "can see . . . ."

Important Dependency Relations (Head to Dependent)

De Marneffe, Dozat, Silveira, Haverinen, Ginter, Nivre, Manning

Functional categories used as edge labels

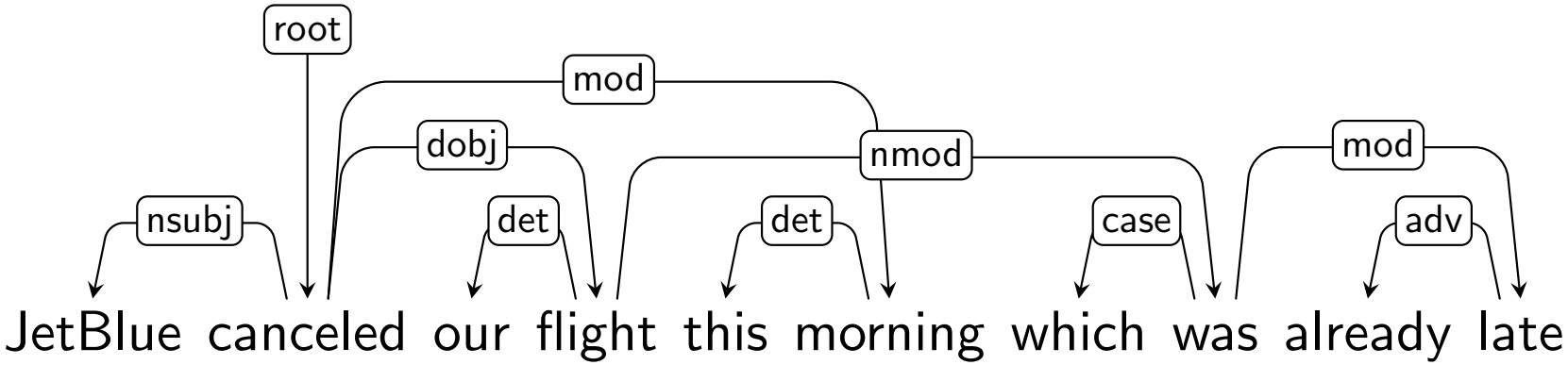
Clausal Argument	*Description*	*Example*
NSUBJ	Nominal subject	Ian ate a cake
DOBJ	Direct object ≈ accusative	Bhavana gave Amitha a cake
IOBJ	Indirect object ≈ dative	Bhavana gave Amitha a cake
CCOMP	Clausal complement	I know the cake contains sugar
XCOMP	Open clausal complement	Arvind learned to bake a cake
Nominal Modifier	*Description*	
NMOD	Nominal modifier	cake platter
AMOD	Adjectival modifier	fluffy cake
NUMMOD	Numeric modifier	three main ingredients
APPOS	Appositional modifier	Sam, the baker, brought cake
DET	Determiner	Kyle's cake
CASE	Prepositions, postpositions, and other case markers	The icing on the cake
Other	*Description*	
CONJ	Conjunct	Luke likes cake and syrup
CC	Coordinating conjunction	Luke likes cake and syrup

Formal Properties of Dependencies

- A dependency graph is a tree
  - Single designated ROOT
  - Each vertex except the root depends on exactly one vertex
  - Thus, a unique path from ROOT to each vertex
- Projectivity
  - Dependencies don't cross with respect to word order
  - Any vertices that lie between a head and dependent pair descend from that head
- Dependency trees generated from CFGs are projective
- Projectivity is not suitable for free word order languages

Example Violating Projectivity

Projectivity is often too restrictive an assumption

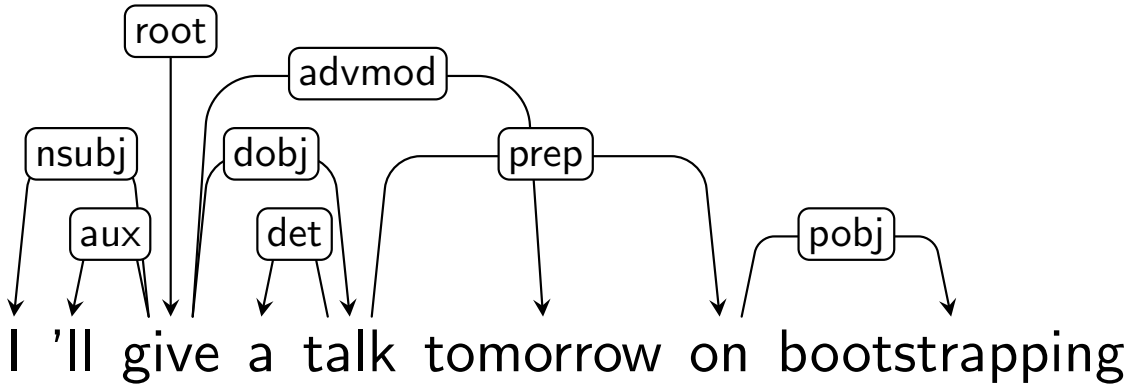


Projectivity fails for free word order languages

Example Violating Projectivity

Projectivity is often too restrictive an assumption

- This is Manning's example with dependency types added
- Notice that, unlike modern approaches, it
  - Uses older dependency relations: PREP versus CASE
  - Treats *on* as the head of *on bootstrapping*



Dependency Treebanks

Set of sentences along with a reference dependency tree for each

- Create from scratch by hand
  - Annotation guidelines in the Universal Dependencies project, for example
- Convert constituency parses to dependency structures
- For any constituent
  - Identify its head child and nonhead children
  - Make the head of each nonhead child depend on the head of the constituent's head child
- Information the original trees lack is omitted from the dependency structure either

Example: Convert Constituent Parse to Dependency Structure

Book the flight through Houston

- Build a constituent parse
- Convert to dependency structure

Case Study: Bootstrapping a Domain-Specific Sentiment Lexicon

A *segment* is part of one or more sentences that expresses a single sentiment

- Generate a dependency tree for each segment
- Remove all relations except some selected types (next page)
- Apply heuristics to add or modify relations, e.g., to handle negation
- Associate candidate dependency triples with sentiment (review ratings)
- Select sufficiently frequent triples that associate with one sentiment (positive, neutral, negative)

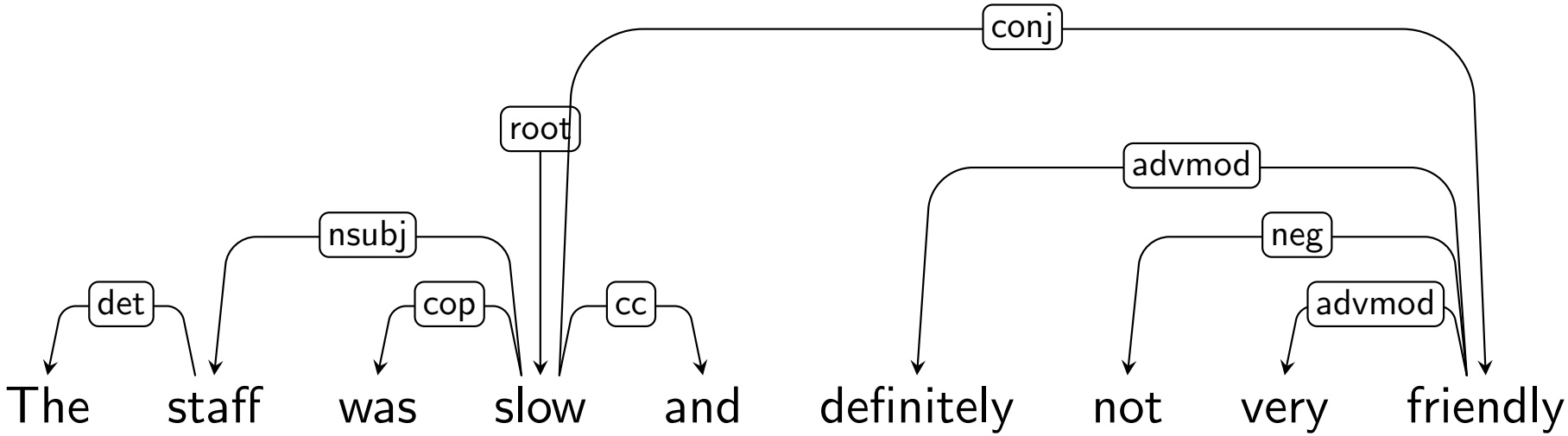
(Work with Zhe Zhang)

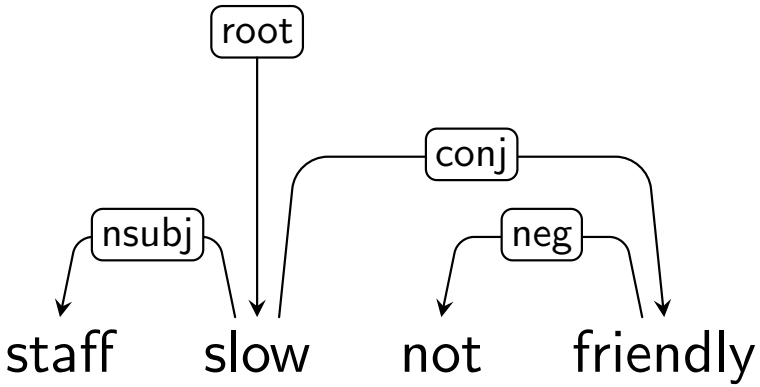
Selected Dependency Relations

- Adjectival modifier: amod
  - e.g., "Great hotel, friendly helpful staff."
  - $\hookrightarrow$ *amod (hotel, Great)*
- Adjectival complement: acomp
  - e.g., "Pool looked nice especially at night."
  - $\hookrightarrow$ *acomp (looked, nice)*
- Nominal subject: nsubj
  - e.g., "The hotel and staff were perfect."
  - $\hookrightarrow$ *nsubj (perfect, hotel)*
- Negation modifier: neg (no, not, nothing, . . .)
- Conjunction: conj_and
- Preposition: prep_with
- Root: root

Sentiment Lexicon: 1

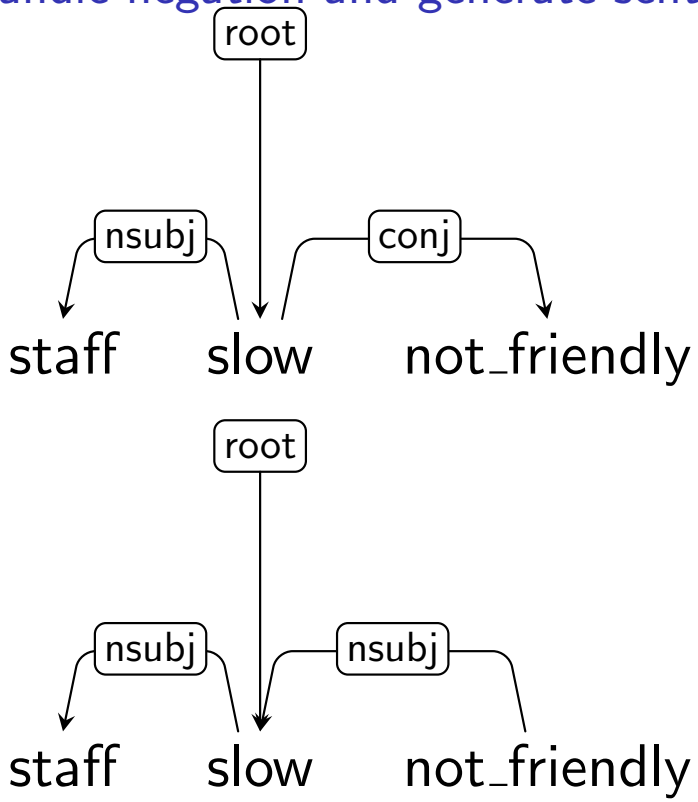
Build dependency parse and discard relations except those given above





Sentiment Lexicon: 2

Handle negation and generate sentiment triples



- New not_friendly node
- The last step is not a dependency tree; also the relationship is nsubj
- Extracted triples: {root_adj(ROOT, slow), nsubj(slow, staff), nsubj(not_friendly, staff)}

Heuristics for Producing Sentiment Triples

Function	**Condition**	**Replace or Assert**
Handle Negation	$neg(w_H, w_D)$	$w_H \leftarrow w_D + \_ + w_H$
Build Relationships (*conj_and* and *amod*)	$amod(w_H, w_i)$ $conj\_and(w_i, w_j)$	$amod(w_H, w_i)$ $amod(w_H, w_j)$
Build Relationships (*conj_and* and *acomp*)	$acomp(w_H, w_i)$ $conj\_and(w_i, w_j)$	$acomp(w_H, w_i)$ $acomp(w_H, w_j)$
Build Relationships (*conj_and* and *nsubj*)	$nsubj(w_i, w_D)$ $conj\_and(w_i, w_j)$	$nsubj(w_i, w_D)$ $nsubj(w_j, w_D)$

Example: neg(friendly, not) maps to not_friendly

Transition-Based Dependency Parsing

Based on shift-reduce (stack-based) parsing for CFGs

- Configuration
  - Input words and cursor indicating how far read, initially at beginning
  - State of a stack, initially a ROOT node
  - Output dependency tree
- Shift: move token from input to stack (working memory)
- Reduce: assert a head-dependent relation involving the top token and another token from the stack
  - Either of them could be the head
- Transitions between configurations
  - Shift
  - Reduce
- Terminal configuration
  - Input processed in its entirety
  - Empty stack: nothing dangling
  - Dependency tree: as constructed—thus rooted at ROOT

Arc Standard Parser: Greedy Approach but Works Well

Terminal state: ROOT is at the top of the stack

- Transition: Left arc
  - Prerequisite: Two or more elements are on the stack
  - Prerequisite: ROOT is not the second word since ROOT cannot be a dependent of anything
  - Assert: word at stack top as head of the next word
  - Remove the lower word from the stack
- Transition: Right arc
  - Prerequisite: Two or more elements are on the stack
  - Assert: word at stack top as dependent of the next word
  - Remove the upper word from the stack
- Transition: Shift
  - Remove word from input
  - Push that word on top of the stack

Need an *oracle*, a way to choose the dependency relation asserted in the Left Arc and Right Arc transitions

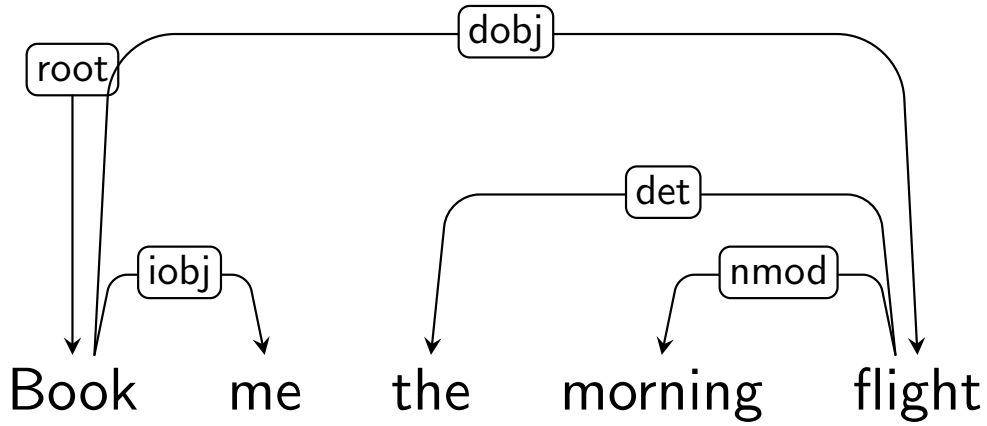
Arc Standard Parser: Exercise

Book me the morning flight

- What is an edge in a dependency parse?
- Which elements are reduced?
- Which of these becomes the head?

Arc Standard Parser Example

Error in the book about iobj versus dobj



- Exercise: Let's work out an execution that produces this parse
- Reduction order
  1. Right arc: book $\rightarrow$ me
  2. Left arc: morning $\leftarrow$ flight
  3. Left arc: the $\leftarrow$ flight
  4. Right arc: book $\rightarrow$ flight
  5. Right arc: root $\rightarrow$ book

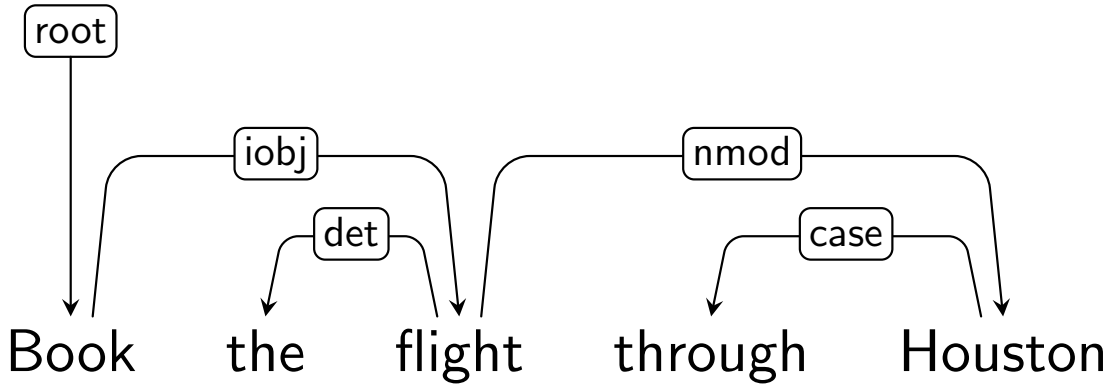
Building a Training Set

Begin from a dependency treebank linking each sentence to a reference dependency parse

On parsing each sentence, for each configuration

- Choose Left Arc if
  - It produces a dependency relation present in the reference parse
- Choose Right Arc if
  - It produces a dependency relation present in the reference parse
  - All dependents of the word at the top in the reference parse have been handled
    - If there is an out-edge from the word in the tree, leave it alone
- Choose Shift otherwise

Arc Standard Training Example



- Exercise: Let's work out an execution that learns from this parse
- Reductions are considered in this order:
  1. Left arc: root $\leftarrow$ book: not present in reference parse
  2. Right arc: root $\rightarrow$ book: would lose book prematurely, so No!
  3. Left arc: the $\leftarrow$ flight
  4. Right arc: book $\rightarrow$ flight: would lose flight prematurely, so No!
  5. Left arc: through $\leftarrow$ Houston
  6. Right arc: flight $\rightarrow$ Houston
  7. Right arc: book $\rightarrow$ flight
  8. Right arc: root $\rightarrow$ book (safe to do so after book's out-edges)

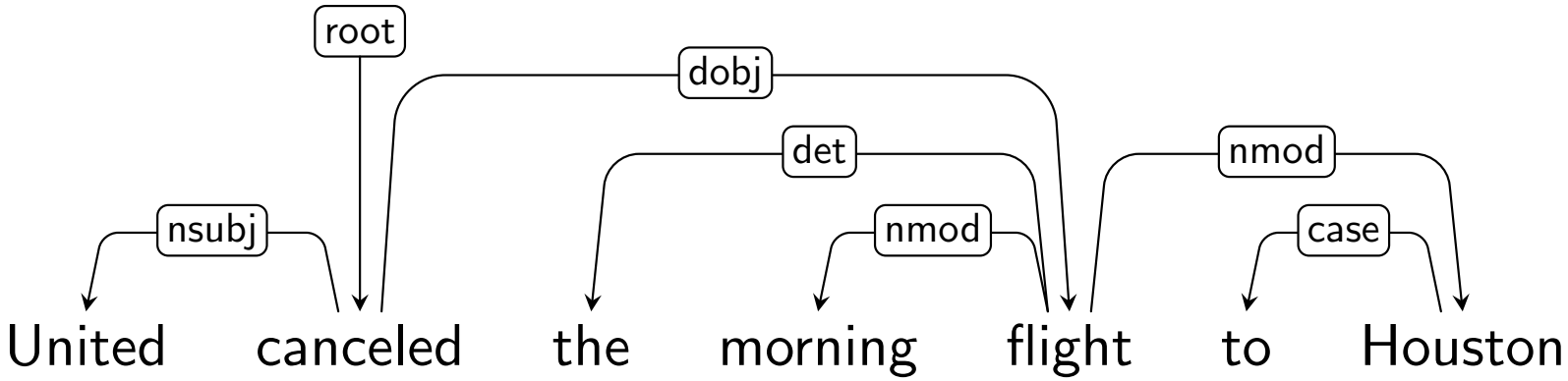
What Training Set is Acquired from the Previous Example

Give a series of snapshots as the example develops

Features Useful for Training a Dependency Parser

- Generally valuable features (as for POS tagging)
  - Word form
  - Lemmas
  - Parts of speech
- Language-specific morphosyntactic features, e.g., case marking
- Too many possible configurations and stack contents
  - Words near the top of the stack are more relevant
  - Relations between such words
  - Upcoming words in the input
- Feature templates pairing *location* and *property*
  - Locations: stack (s_i), input buffer (b_j), set of relations (r)
  - Properties of locations: word form (w), lemma (l), POS (t)
  - Example: feature of "word form at top of stack" is s_1.w
  - Example: feature of "word form at top of stack and its POS" is s_1.wt
- Composite templates concatenate two or more templates

Example of Applying Feature Templates: 1



Example of Applying Feature Templates: 2

When we have arrived at this configuration

Stack	Word buffer	Relations
root, canceled, flights	for Houston	canceled $\rightarrow$ United
		flights $\rightarrow$ morning
		flights $\rightarrow$ the

Compute the feature values

Feature	Transition
$s_1.w$ = flights	Shift
$s_2.w$ = canceled	Shift
$s_1.t$ = NNS	Shift
$s_2.t$ = VBD	Shift
$b_1.w$ = to	Shift
$b_1.t$ = TO	Shift
$s_1.wt$ = flightsNNS	Shift
$s_1.t \circ s_2.t$ =NNSVBD	Shift

Evaluation

- Unlabeled attachment accuracy
  - Based on head assigned to each word
  - Ignores dependency relation
- Labeled attachment accuracy
  - Accounts for dependency relation