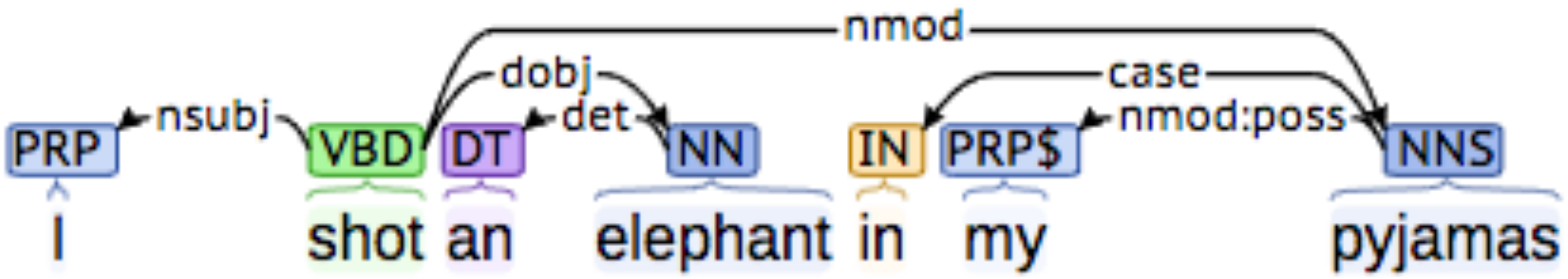


COMP90042 LECTURE 7

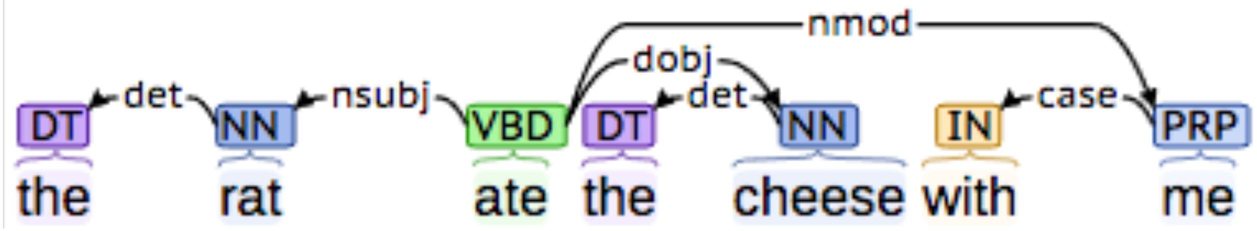
DEPENDENCY GRAMMAR & PARSING

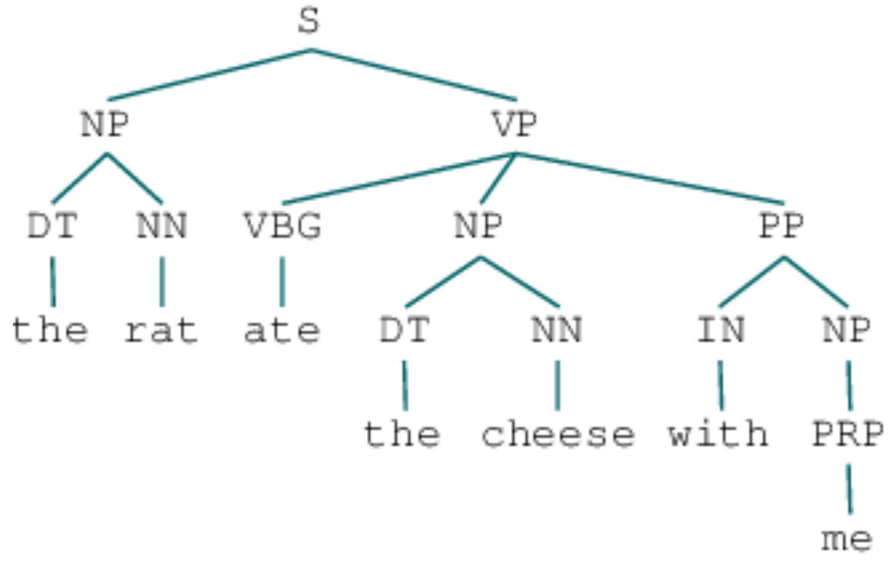
OUTLINE

- Dependency grammars
- Projectivity
- Parsing methods
  - transition-based parsing
  - graph-based

DEPENDENCY GRAMMAR

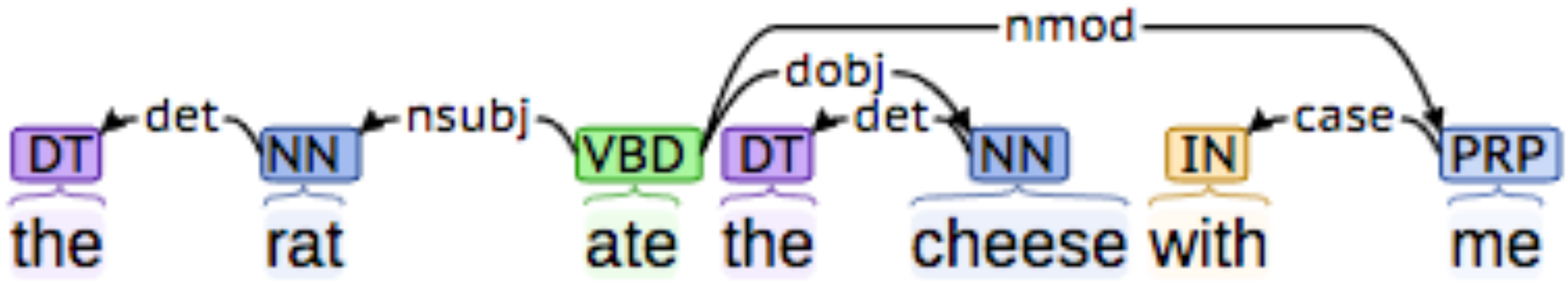
- *phrase-structure grammars* assume a *constituency tree* which identifies the *phrases* in a sentence
    - based on idea that these phrases are interchangable (e.g., swap an NP for another NP) and maintain grammaticality
- *dependency grammar* offers a simpler approach
    - describe binary relations between pairs of words
    - namely, between *heads* and *dependents*
- Building on notion of *head* as seen in phrase-structure parsers…





WHAT IS A DEPENDENCY?

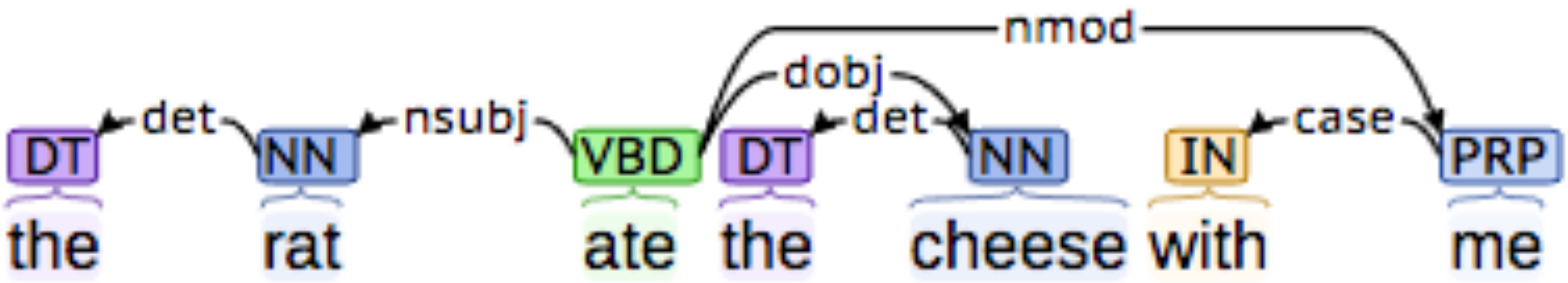
- Links between a *head* word and its *dependent* words in the sentence: either *syntactic roles* or *modifier relations*



- *argument* of a predicate, e.g., *ate(rat, cheese)*
  - *rat* is the *subject* of verb *ate* (thing doing the eating)
  - *cheese* is the *direct object* of verb ate (thing being eaten)
- head may determine *type* of relation, lexical form of dependent etc
  - verb-subject agreement, *I talk to myself*, vs **me talk to I*
  - agreement often for gender, number and case

WHAT IS A DEPENDENCY II

- Various other types of dependencies exist
  - a *modifier* which is typically optional (aka *adjunct*)
    - (with) *me* modifies the act of (the rat) *eating*
  - *specifiers*, e.g., *the rat*, *the cheese*, *with me*
    - help to specify the referent (which rat?), the head's relation, etc.

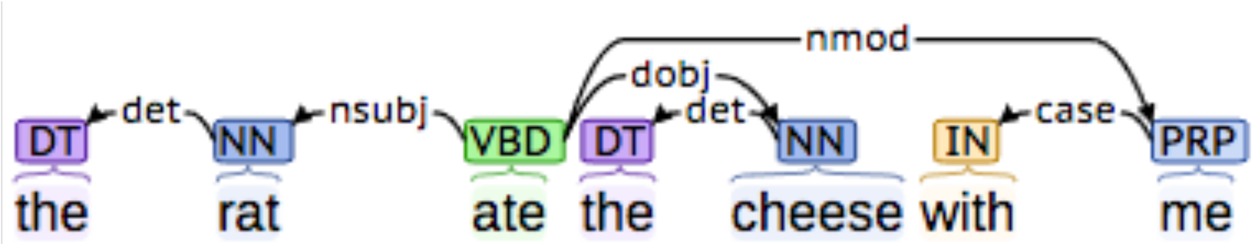


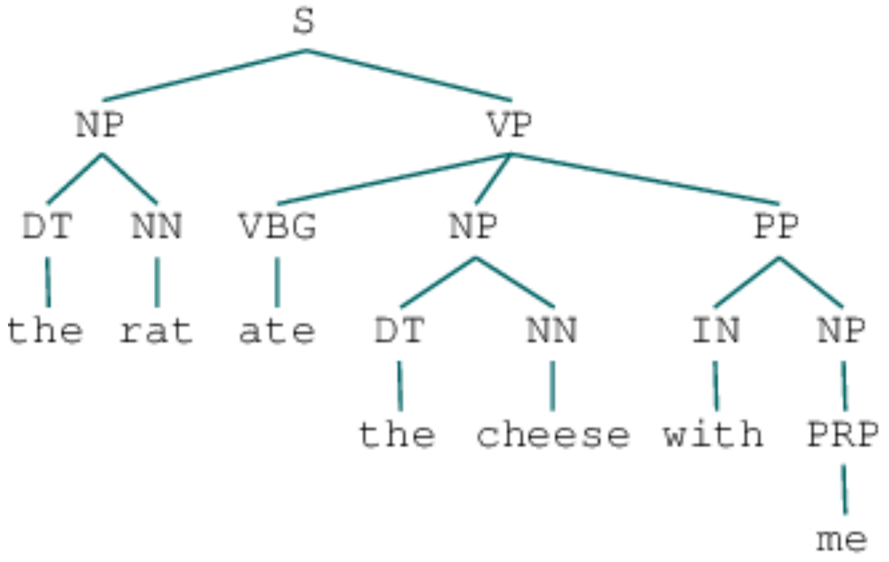
DEPENDENCY TYPES

- Edges labelled with the dependency *type*, *e.g.*, *Stanford types*, *e.g.*, sample types (key: *head*, **dependent**)
  - NSUBJ **Julian** *speaks* Chinese
    (nominal subject)
  - DOBJ Trevor *presented* a **lecture** in English
    (direct object)
  - IOBJ Morpheus *gave* **Neo** the red pill
    (indirect object)
  - APPOS *Neo*, the main **character**, swallowed the pill
    (appositive)
- See reading for more!

WHY DEPENDENCIES?

- Dependency tree more directly represents the core of the sentence: *who did what to whom?*
  - captured by the links incident on verb nodes, e.g., NSUBJ, DOBJ etc; easier to answer questions like:
    - what was the main thing being expressed in the sentence (*eat*)

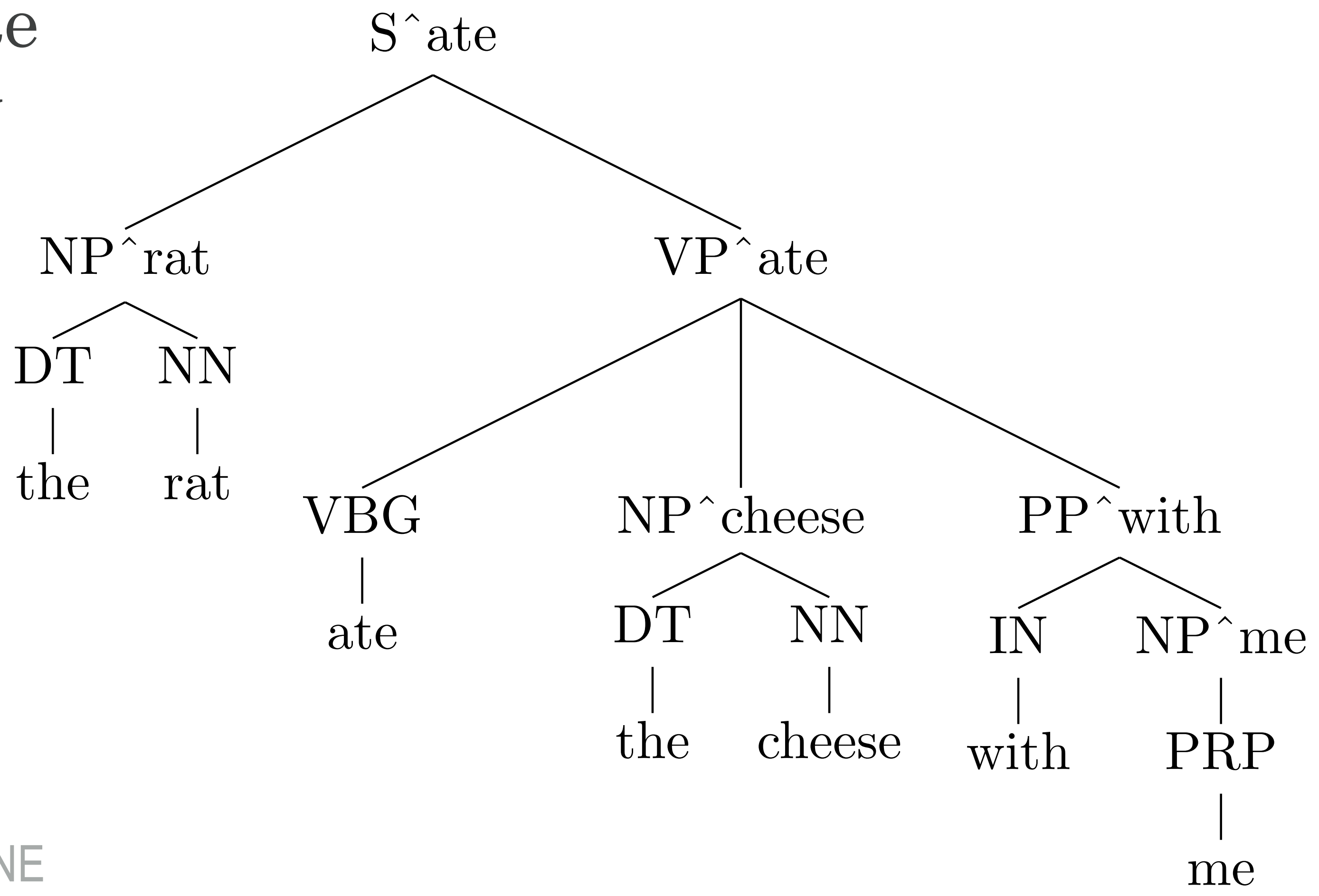




  - more minor details are buried deeper in the tree (e.g., adjectives, determiners etc)

DEPENDENCY VS HEAD

- Close similarity with ‘head’ in phrase-structure grammars
  - the ‘head’ of an XP is (mostly) an X,
    i.e., noun in a NP, verb in a VP etc.
    see https://en.wikipedia.org/wiki/Head_(linguistics)
  - main dependency edges captured in rewrite rules
    - S^ate -> NP^rat VP^ate
      captures dependency
      rat ← ate



DEPENDENCY *TREE*

- Dependency edges form a *tree*
  - each node is a *word token*
  - one node is chosen as the *root*
  - directed edges link heads and their dependents
- Cf. phrase-structure grammars
  - forms a hierarchical tree
  - word tokens are the *leaves*
  - internal nodes are ‘constituent phrases’ e.g., NP, VP etc
- Both use part-of-speech

(NON-)PROJECTIVITY

- A tree is *projective* if, for all arcs from head to dependent
  - there is a path from the head to every word that lies between the head and the dependent
- More simply, the tree can be drawn on a plane without any arcs crossing
- Most sentences are projective, however exceptions exist (fairly common in other languages)

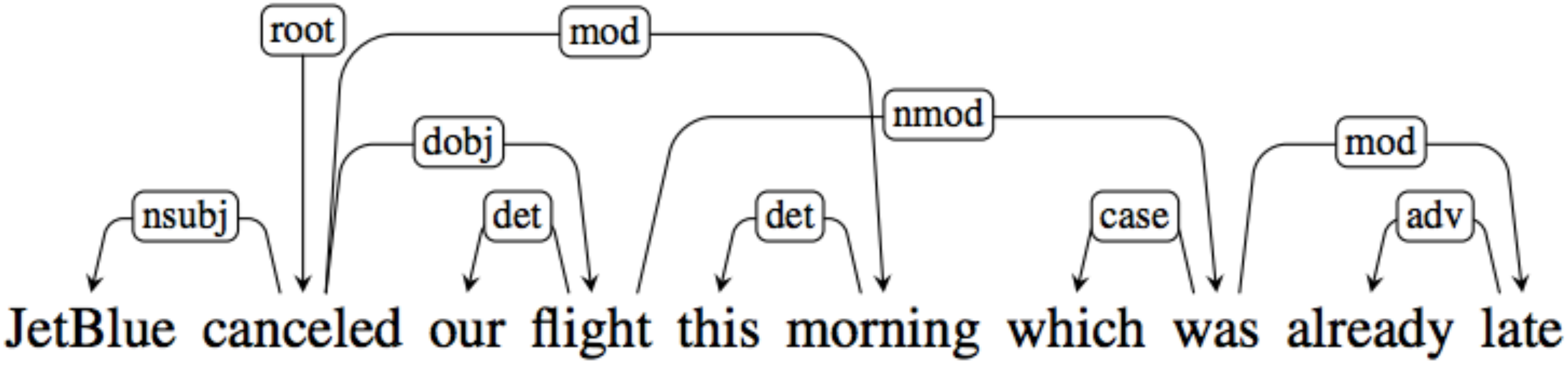

root
mod
nmod
dobj
mod
nsubj
det
det
case
adv
JetBlue canceled our flight this morning which was already late

Figure JM3, Ch 14

DEPENDENCY GRAMMAR

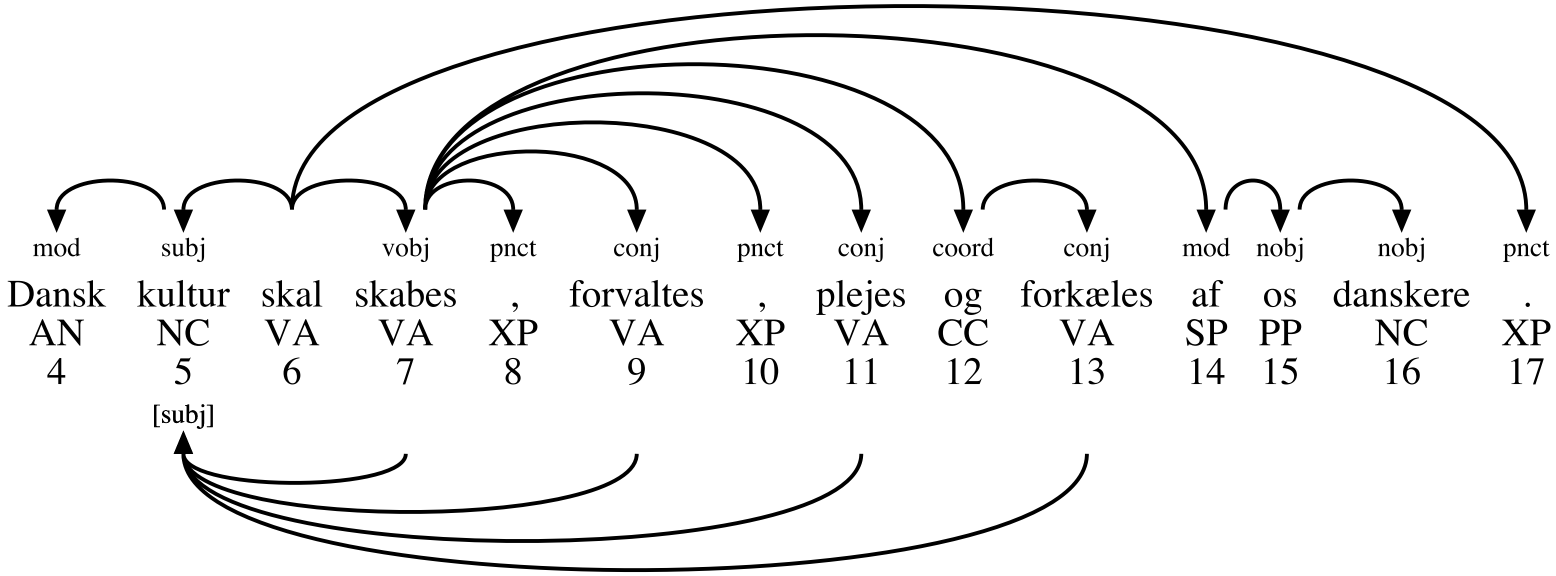
- Not really a grammar, in sense of a '*generative grammar*'
  - cannot be said to define a language, unlike a context free grammar
  - any structure is valid, job of *probabilistic model* to differentiate between poor and good alternatives
- However, very practical and closely matches what we want from a parser (most often predicates & arguments)

DEPENDENCY TREEBANKS

- A few dependency treebanks
  - Czech, Arabic, Danish, Dutch, Greek, Turkish …
- Many more phrase-structure treebanks, which can be *converted* into dependencies
- More recently, *Universal Dependency Treebank*
  - collates 70 treebanks, 50 languages
  - unified part-of-speech, morphology labels, relation types
  - consistent handling of conjunctions and other tricky cases
- http://universaldependencies.org/

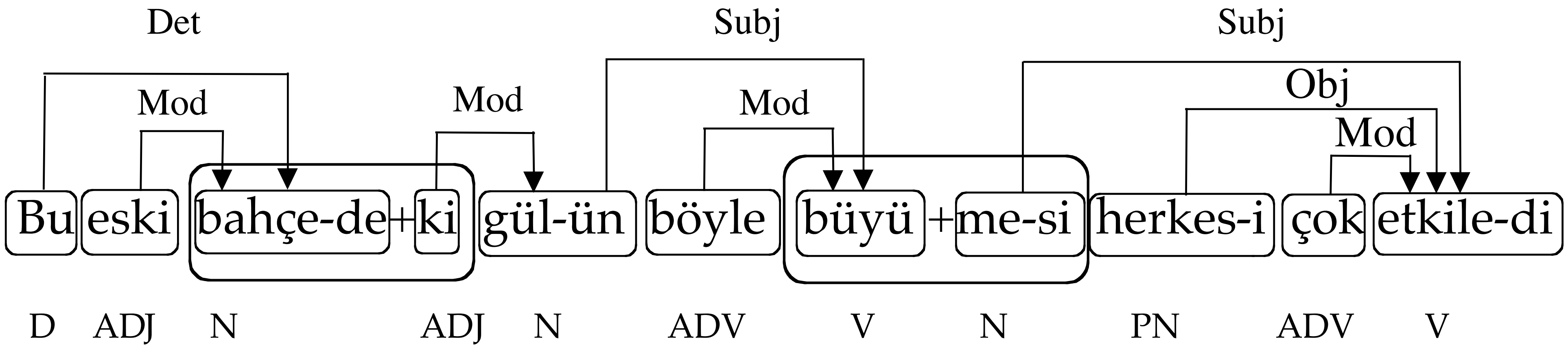
EXAMPLES FROM TREEBANKS

- 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 Netherlands, 2003. 261-277.

DEPENDENCY PARSING

- Parsing: task of finding the *best* structure for a given input sentence
  - i.e., $\arg\max_t \text{score}(\boldsymbol{t} \mid \boldsymbol{x})$
- Two main approaches:
  - *graph-based*: uses *chart* over possible parses, and dynamic programming to solve for the maximum
  - *transition-based*: treats problem as incremental sequence of decisions over next action in a state machine

TRANSITION BASED PARSING

- Frames parsing as sequence of simple parsing transitions
  - maintain two data structures
    - *buffer* = input words yet to be processed
    - *stack* = head words currently being processed
  - two types of transitions
    - *shift* = move word from buffer on to top of stack
    - *arc* = add arc (left/right) between top two items on stack (and *remove* dependent from stack)

TRANSITION BASED PARSING ALGORITHM

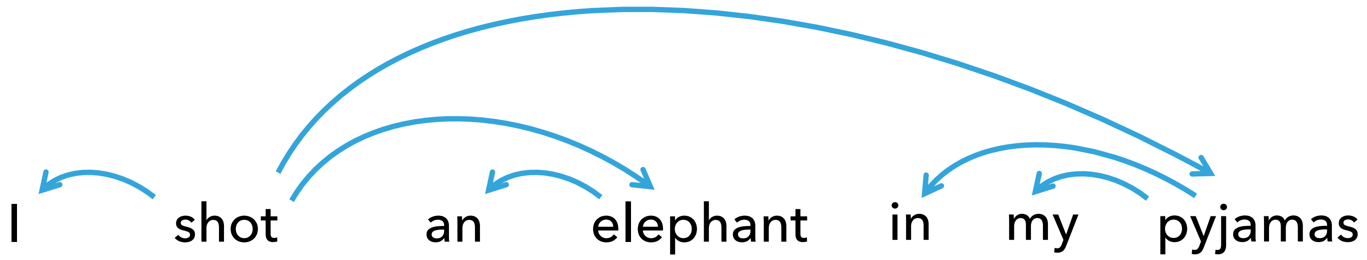
- For each word in input (buffer)
  - *shift* current word from buffer onto stack
  - while there are 2 or more items on stack:
    - either:
      - a) add an *arc (left or right)* between top two items, and remove the dependent; or
      - b) continue to outer loop
- Finished when buffer empty & stack has only 1 item
- Always results in a *projective tree*

EXAMPLE

- I shot an elephant in my pyjamas

Buffer	Stack	Action
I shot an elephant in my pyjamas		Shift

Generated parse:



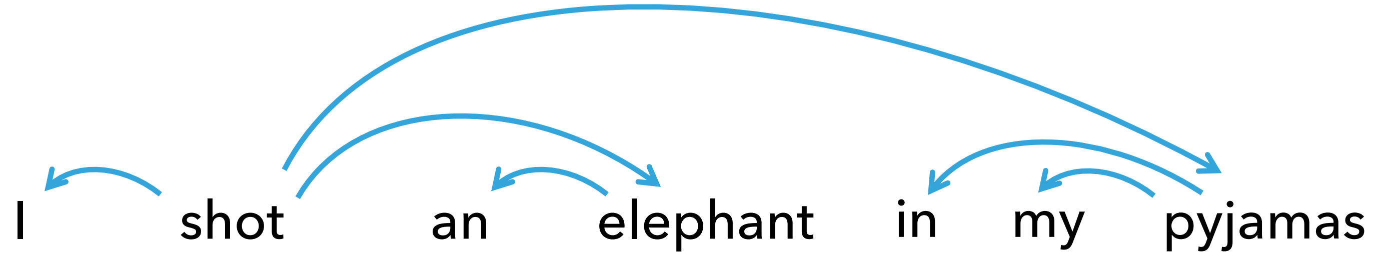
I shot an elephant in my pyjamas

EXAMPLE

- I shot an elephant in my pyjamas

Buffer	Stack	Action
I shot an elephant in my pyjamas		Shift
shot an elephant in my pyjamas	I	Shift
an elephant in my pyjamas	I, shot	Arc-left
an elephant in my pyjamas	shot	Shift
elephant in my pyjamas	shot, an	Shift
in my pyjamas	shot, an, elephant	Arc-left
in my pyjamas	shot, elephant	Arc-right
in my pyjamas	shot	Shift
...	...	...
	shot	<done>

Generated parse:

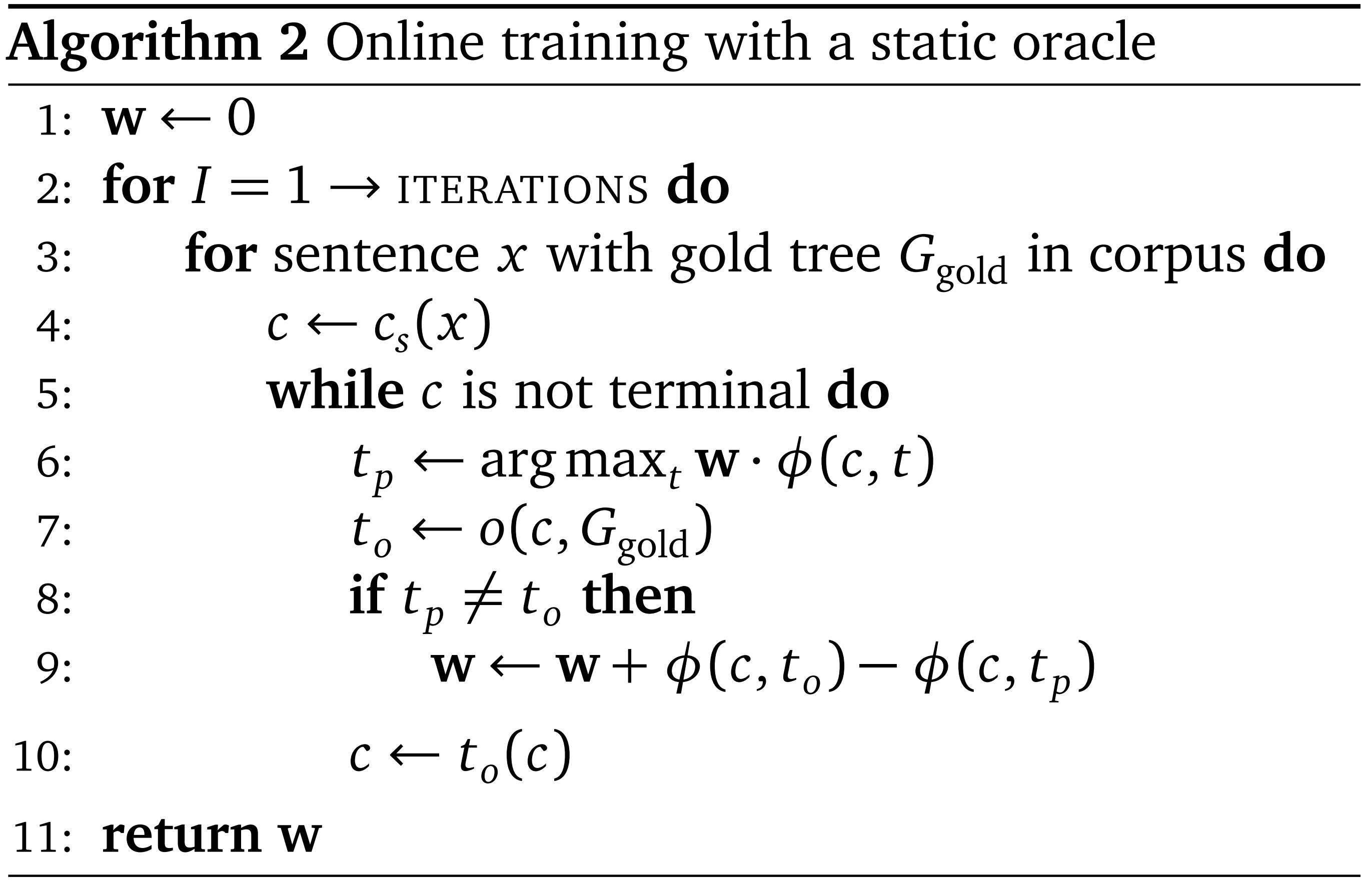


TRANSITION BASED PARSING MODELS

- How do we know when to *arc* and whether to add *left* or *right* facing arcs?
- Use a scoring function, *score(buffer, stack, transition)*, based on the state, i.e.,
  - the next word(s) in the buffer
  - the contents of the stack, particularly the top two items
  - the transition type, one of *{continue, arc-left, arc-right}*
- Then select the *transition* with the highest score!

TRANSITION BASED SCORING

- Form a feature representation for the state
  - e.g., stack top has tag NN & next in stack has tag DT & transition = arc-left
  - learn a *weight* for each feature of this type, in order that the parser predicts the correct next action
- E.g., *percepton training*



Algorithm 2 Online training with a static oracle

```
$\mathbf{w} \leftarrow 0$
for $I = 1 \rightarrow$ ITERATIONS do
    for sentence $x$ with gold tree $G_{\text{gold}}$ in corpus do
        $c \leftarrow c_s(x)$
        while $c$ is not terminal do
            $t_p \leftarrow \arg\max_t \mathbf{w} \cdot \phi(c, t)$
            $t_o \leftarrow o(c, G_{\text{gold}})$
            if $t_p \neq t_o$ then
                $\mathbf{w} \leftarrow \mathbf{w} + \phi(c, t_o) - \phi(c, t_p)$
            $c \leftarrow t_o(c)$
return $\mathbf{w}$
```

from Goldberg & Nivre (2012)

A FINAL WORD

- Dependency parsing a compelling, alterative, formulation to constituency parsing
  - structures based on words as internal nodes
  - edges encode word-word syntactic and semantic relations
  - often this is the information we need for other tasks!
- Transition-based parsing algorithm
  - as sequence of shift and arc actions
- Graph-based parsing (not covered)
  - uses classic dynamic programming methods (similar to CYK)

REQUIRED READING

- J&M3 Ch. 14
- **(Just for fun)** Goldberg, Yoav, and Joakim Nivre. "A Dynamic Oracle for Arc-Eager Dependency Parsing." *COLING*. 2012. https://www.aclweb.org/anthology/C/C12/C12-1059.pdf