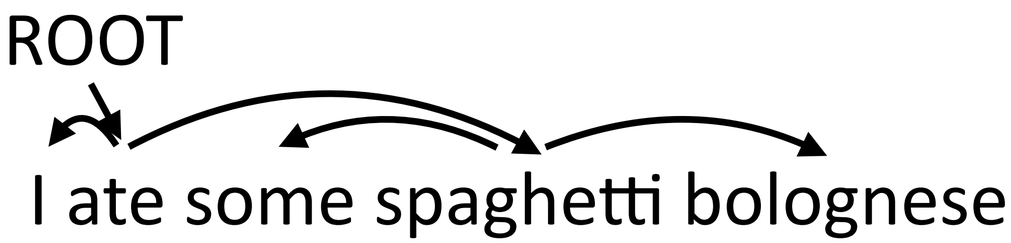
Transition-based Parsing

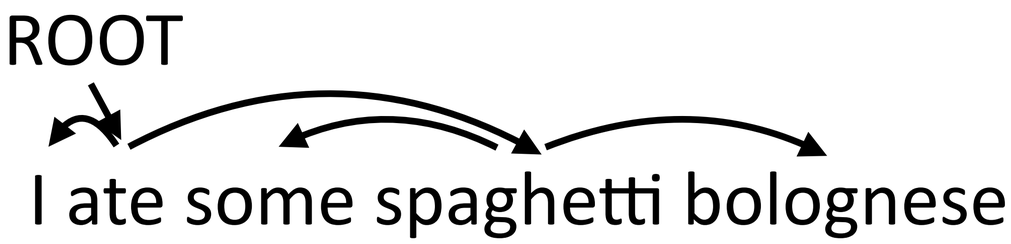
- We can build a dependency parser using a chart-based algorithm like CKY
  - Time: $O(n^3)$, but the algorithm is very tricky!
- *Transition-based*, or *shift-reduce*, is another style of parser; similar to deterministic parsing for compilers
- A tree is built from a sequence of incremental decisions moving left to right through the sentence
- Stack contains partially-built tree, buffer contains rest of sentence

Transition System



- Initial state: Stack: [ROOT] Buffer: [I ate some spaghetti bolognese]
- Shift: top of buffer -> top of stack
  - Shift 1: Stack: [ROOT I] Buffer: [ate some spaghetti bolognese]
  - Shift 2: Stack: [ROOT I ate] Buffer: [some spaghetti bolognese]

Transition System



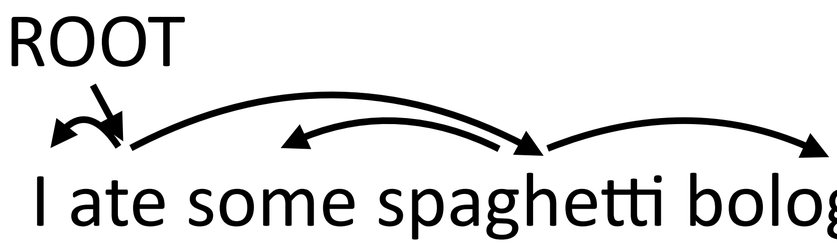
- State: Stack: [ROOT I ate] Buffer: [some spaghetti bolognese]

- Left-arc (reduce): Let σ denote the stack, $\sigma|w_{-1}$ = stack ending in w_{-1}
  - "Pop two elements, add an arc, put them back on the stack"

$$\boxed{\sigma|w_{-2}, w_{-1}} \rightarrow \boxed{\sigma|w_{-1}}$$ w_{-2} is now a child of w_{-1}

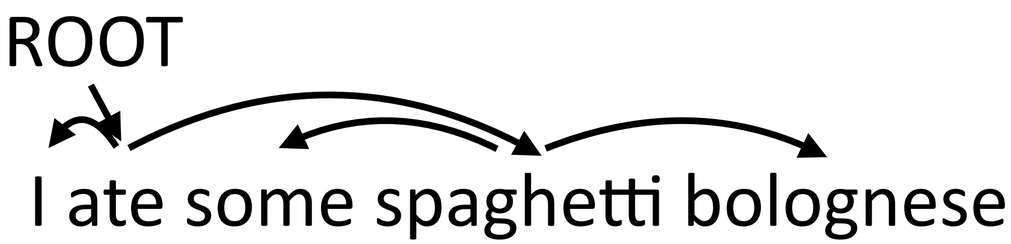
- State: Stack: [ROOT ate] Buffer: [some spaghetti bolognese]

Arc-Standard Parsing

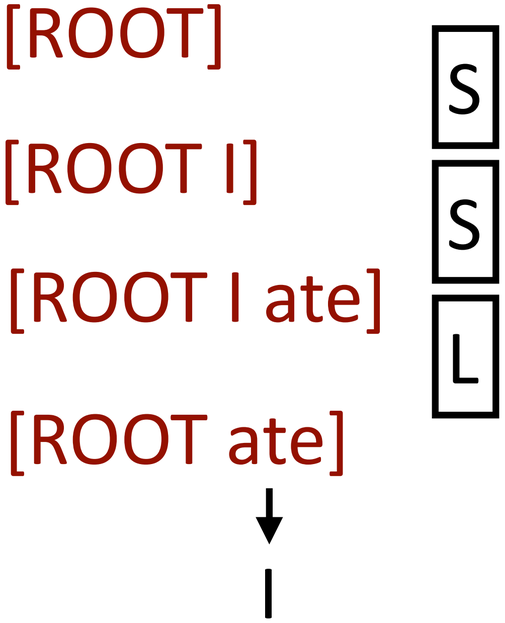


- Start: stack: [ROOT], buffer: [I ate some spaghetti bolognese]
- Arc-standard system: three operations
  - Shift: top of buffer -> top of stack
  - Left-Arc: $\boxed{\sigma|w_{-2}, w_{-1}} \rightarrow \boxed{\sigma|w_{-1}}$, w_{-2} is now a child of w_{-1}
  - Right-Arc $\boxed{\sigma|w_{-2}, w_{-1}} \rightarrow \boxed{\sigma|w_{-2}}$, w_{-1} is now a child of w_{-2}
- End: stack contains [ROOT], buffer is empty []
- How many transitions do we need if we have n words in a sentence?
- There are other transition systems, but we won't discuss these

Arc-Standard Parsing

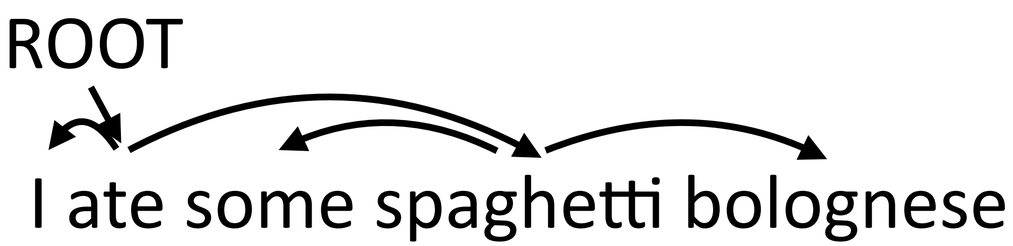


S	top of buffer -> top of stack
LA	pop two, left arc between them
RA	pop two, right arc between them



- Could do the left arc later! But no reason to wait
- Can’t attach ROOT <- ate yet even though this is a correct dependency!

Arc-Standard Parsing



S	top of buffer -> top of stack
LA	pop two, left arc between them
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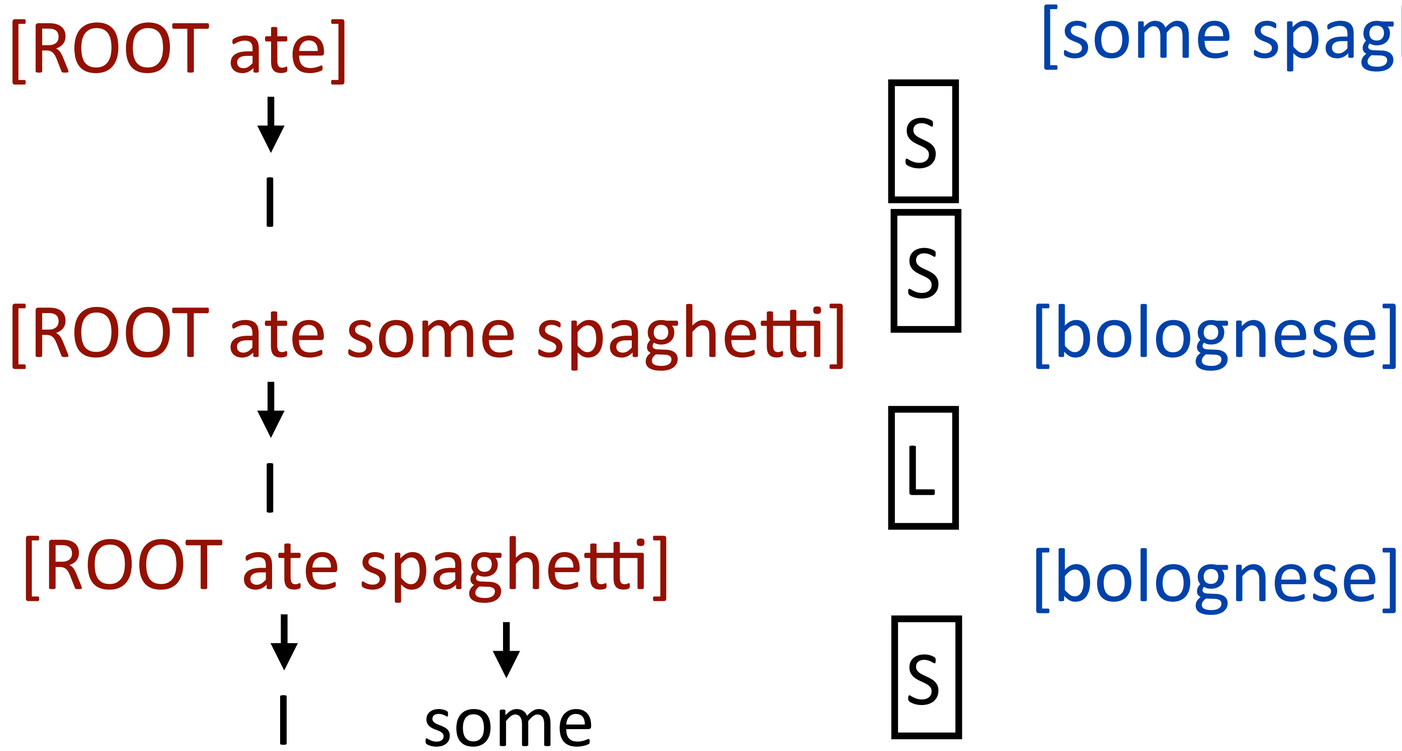
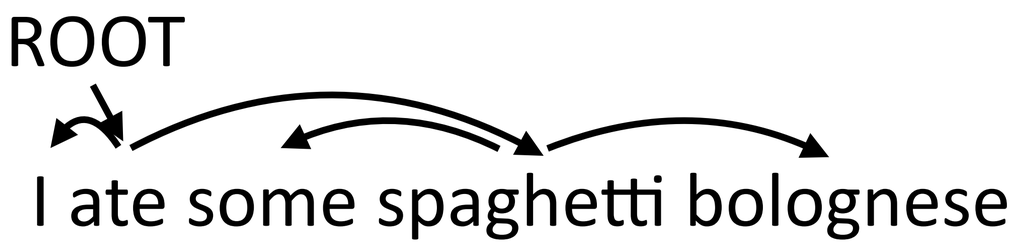


Arc-Standard Parsing



S top of buffer -> top of stack
LA pop two, left arc between them
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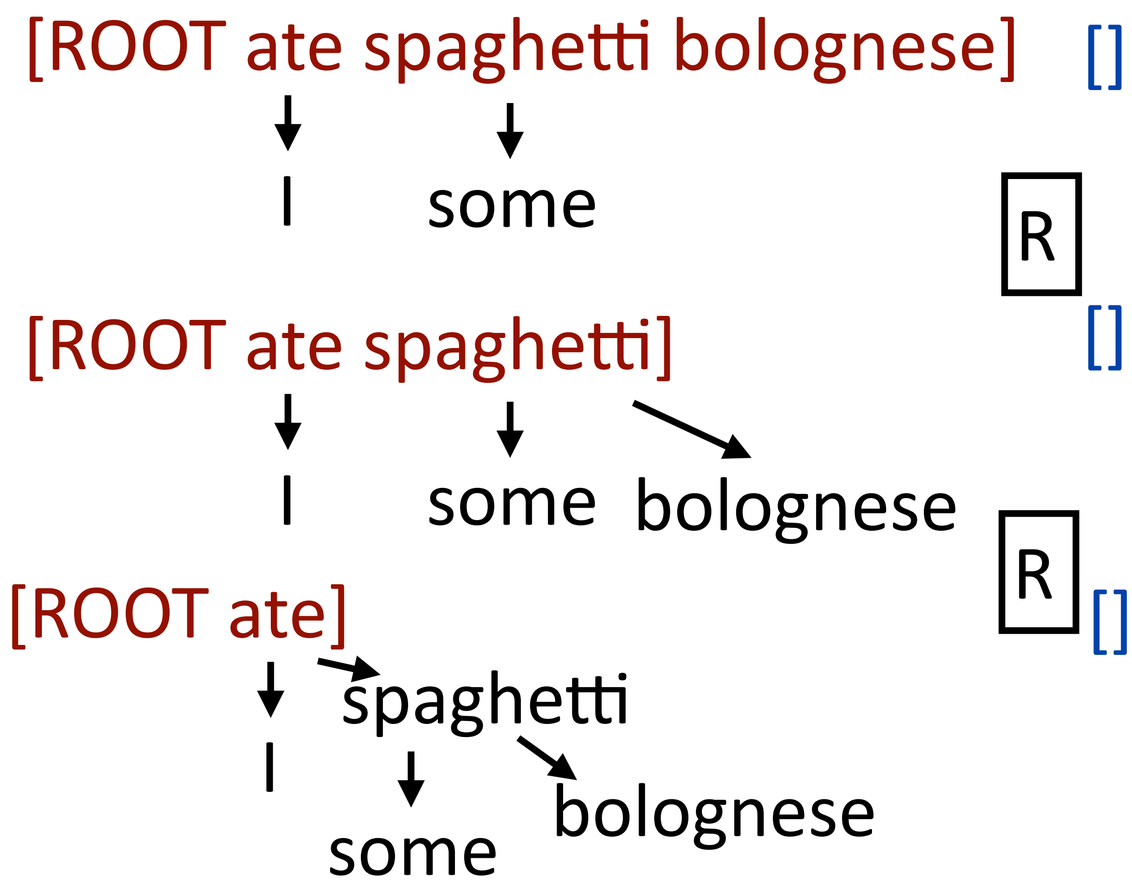
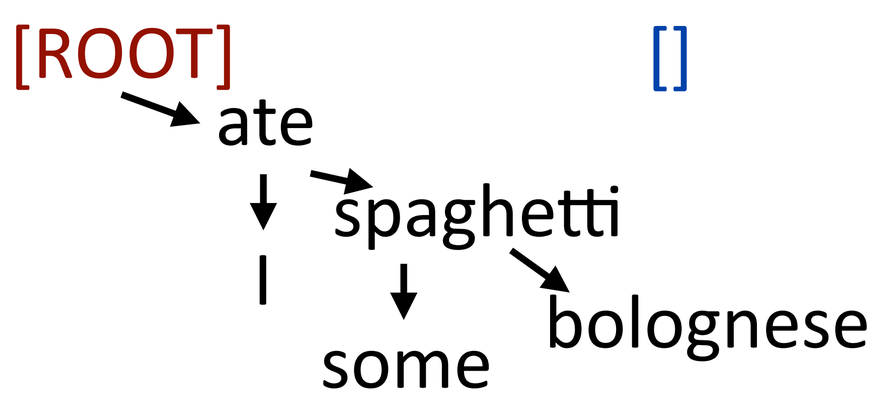


Stack consists of all words that are still waiting for right children, end with a bunch of right-arc ops

Final state:



Building Transition-Based Parsers

[ROOT] [I ate some spaghetti bolognese]

- How do we make the right decision in this case?
- Only one legal move (shift)

[ROOT ate some spaghetti] [bolognese]

- How do we make the right decision in this case? (all three actions legal)
- Multi-way classification problem: shift, left-arc, or right-arc?

$$\text{argmax}_{a \in \{\text{S},\text{LA},\text{RA}\}} w^\top f(\text{stack}, \text{buffer}, a)$$

Features for Shift-Reduce Parsing

[ROOT ate some spaghetti] [bolognese]

- Features to know this should left-arc?
- One of the harder feature design tasks!
- In this case: the stack tag sequence VBD - DT - NN is pretty informative — looks like a verb taking a direct object which has a determiner in it
- Things to look at: top words/POS of buffer, top words/POS of stack, leftmost and rightmost children of top items on the stack

Training a Greedy Model

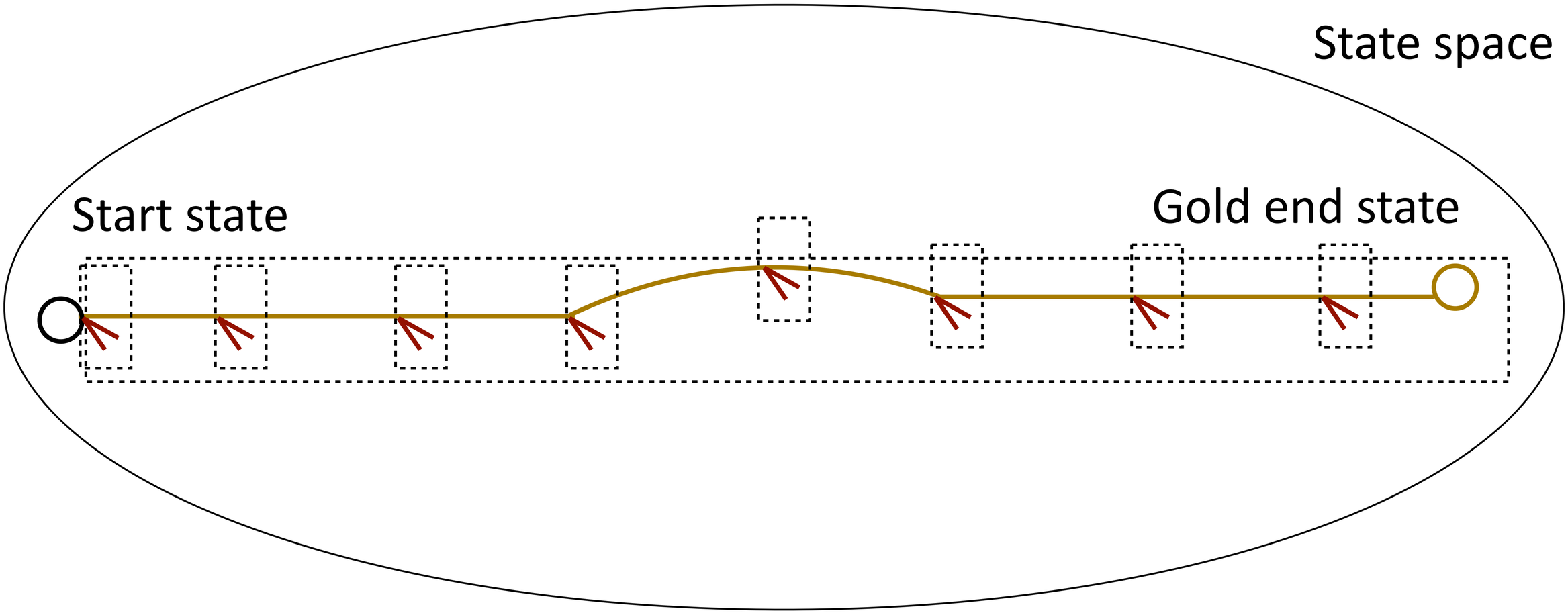
[ROOT ate some spaghetti] [bolognese]

$$\text{argmax}_{a \in \{\text{S},\text{LA},\text{RA}\}} w^\top f(\text{stack}, \text{buffer}, a)$$

- Can turn a tree into a decision sequence ***a*** by building an *oracle*
- Train a classifier to predict the right decision using these as training data

- Training data assumes you made correct decisions up to this point and teaches you to make the correct decision, but what if you screwed up…

Training a Greedy Model



- Greedy: 2n local training examples
- Non-gold states unobserved during training: consider making bad decisions but don't *condition* on bad decisions