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Transition-based dependency parsing

Syntactic analysis (5LN455)

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Based on slides from Marco Kuhlmann

Overview

- Arc-factored dependency parsing
  - Collins' algorithm
  - Eisner's algorithm
- Transition-based dependency parsing
  - The arc-standard algorithm
- Evaluation of dependency parsers
- Projectivity

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Transition-based dependency parsing

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Transition-based dependency parsing

- Eisner's algorithm runs in time $O(|w|^3)$.
  This may be too much if a lot of data is involved.
- Idea: Design a dumber but really fast algorithm and let the machine learning do the rest.
- Eisner's algorithm searches over many different dependency trees at the same time.
- A transition-based dependency parser only builds *one* tree, in *one* left-to-right sweep over the input.

Transition-based dependency parsing

- The parser starts in an initial configuration.
- At each step, it asks a guide to choose between one of several transitions (actions) into new configurations.
- Parsing stops if the parser reaches a terminal configuration.
- The parser returns the dependency tree associated with the terminal configuration.

Generic parsing algorithm

```
Configuration c = parser.getInitialConfiguration(sentence)

while c is not a terminal configuration do

     Transition t = guide.getNextTransition(c)

     c = c.makeTransition(t)

return c.getGraph()
```

Variation

Transition-based dependency parsers differ with respect to the configurations and the transitions that they use.

Guides

- We need a guide that tells us what the next transition should be.
- The task of the guide can be understood as classification: Predict the next transition (class), given the current configuration.

Training a guide

- We let the parser run on gold-standard trees.
- Every time there is a choice to make, we simply look into the tree and do 'the right thing'™.
- We collect all (configuration, transition) pairs and train a classifier on them.
- When parsing unseen sentences, we use the trained classifier as a guide.

Training a guide

- The number of (configuration, transition) pairs is far too large.
- We define a set of features of configurations that we consider to be relevant for the task of predicting the next transition.

  Example: word forms of the topmost two words on the stack and the next two words in the buffer

- We can then describe every configuration in terms of a feature vector.

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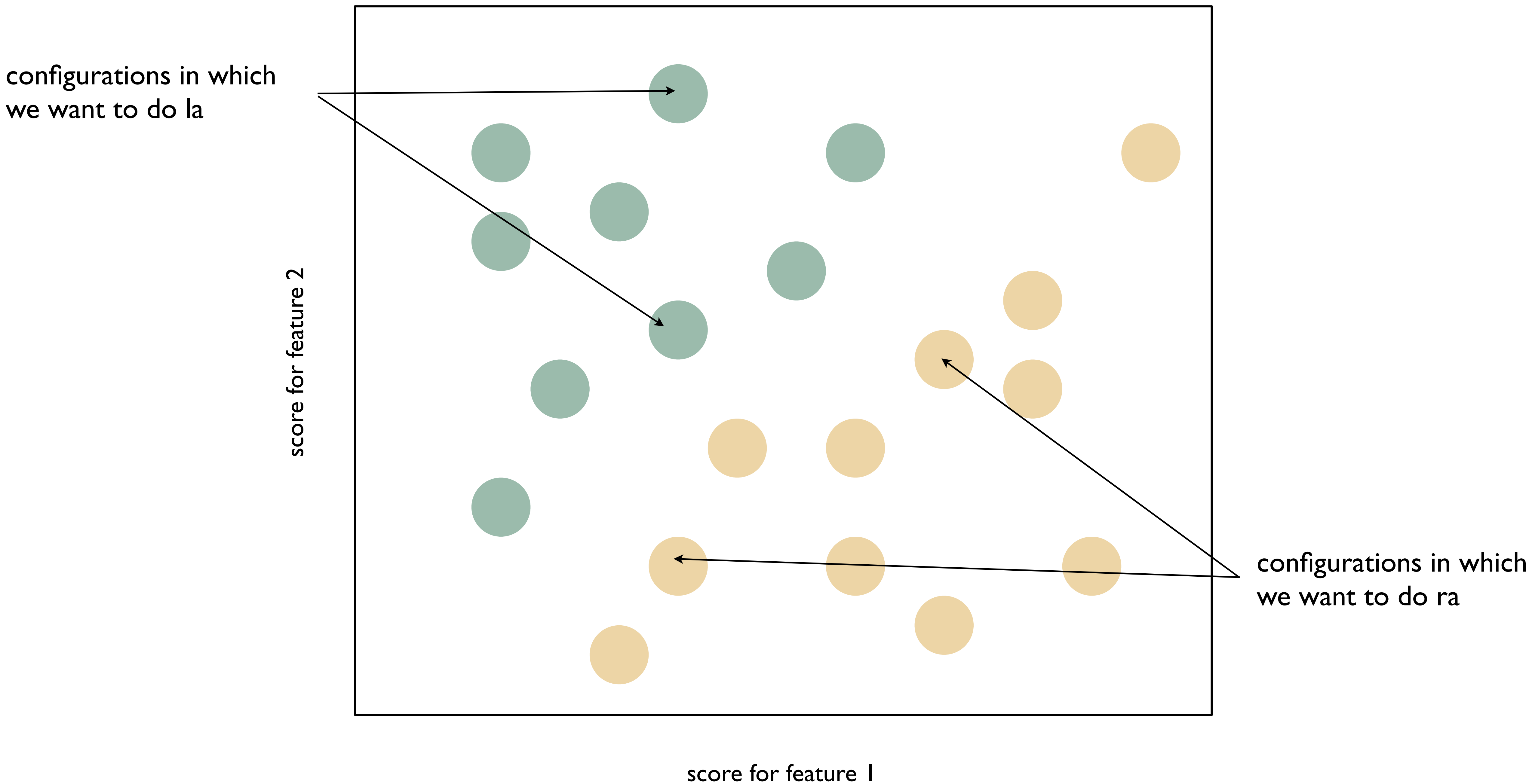
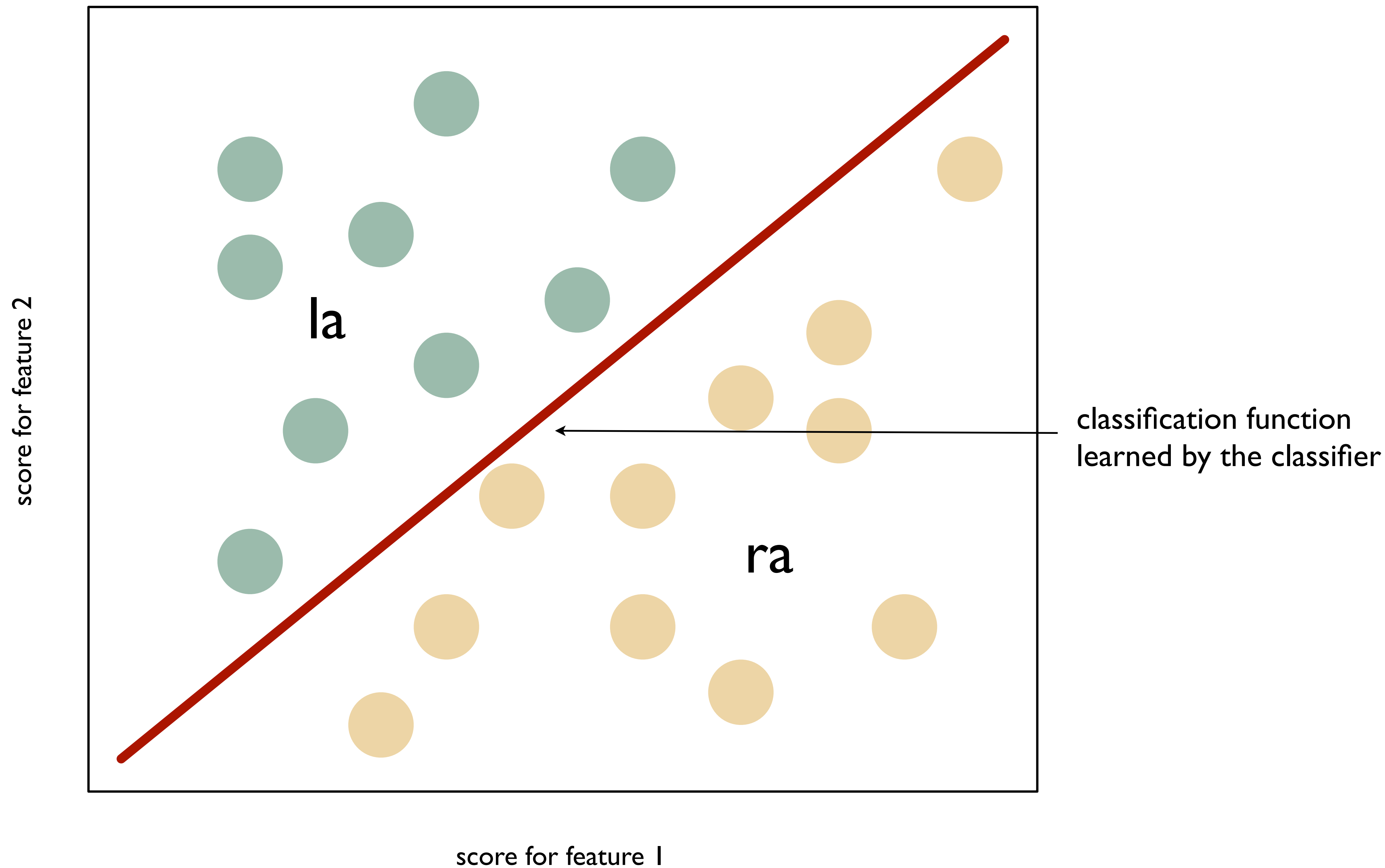
Training a guide



Training a guide



Training a guide

- In practical systems, we have thousands of features and hundreds of transitions.
- There are several machine-learning paradigms that can be used to train a guide for such a task.

Examples: perceptron, decision trees, support-vector machines, memory-based learning

Example features

	Attributes				
Adress	**FORM**	**LEMMA**	**POS**	**FEATS**	**DEPREL**
Stack[0]	X	X	X	X	
Stack[1]			X		
Ldep(Stack[0])					X
Rdep(Stack[0])					X
Buffer[0]	X	X	X	X	
Buffer[1]			X		
Ldep(Buffer[0])					X
Ldep(Buffer[0])					X
. . .					

- Combinations of addresses and attributes (e.g. those marked in the table)
- Other features, such as distances, number of children, ...

The arc-standard algorithm

The arc-standard algorithm

- The arc-standard algorithm is a simple algorithm for transition-based dependency parsing.
- It is very similar to shift–reduce parsing as it is known for context-free grammars.
- It is implemented in most practical transition-based dependency parsers, including MaltParser.

Configurations

A configuration for a sentence $w = w_1 \ldots w_n$ consists of three components:

- a buffer containing words of *w*
- a stack containing words of *w*
- the dependency graph constructed so far

Configurations

- Initial configuration:
  - All words are in the buffer.
  - The stack is empty.
  - The dependency graph is empty.
- Terminal configuration:
  - The buffer is empty.
  - The stack contains a single word.

Possible transitions

- shift (sh): push
  the next word in the buffer onto the stack
- left-arc (la): add an arc
  from the topmost word on the stack, s_1,
  to the second-topmost word, s_2, and pop s_2
- right-arc (ra): add an arc
  from the second-topmost word on the stack, s_2,
  to the topmost word, s_1, and pop s_1

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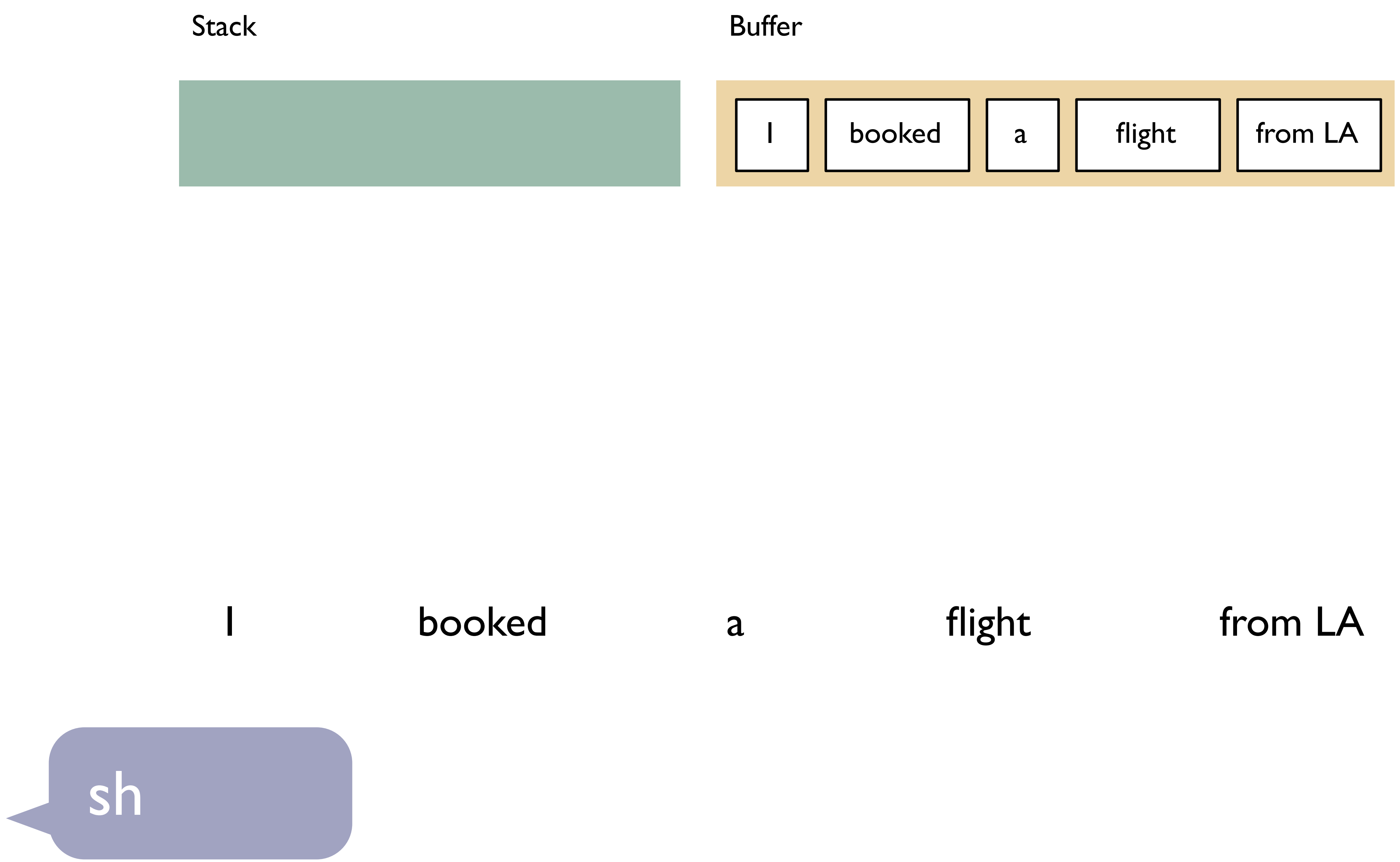
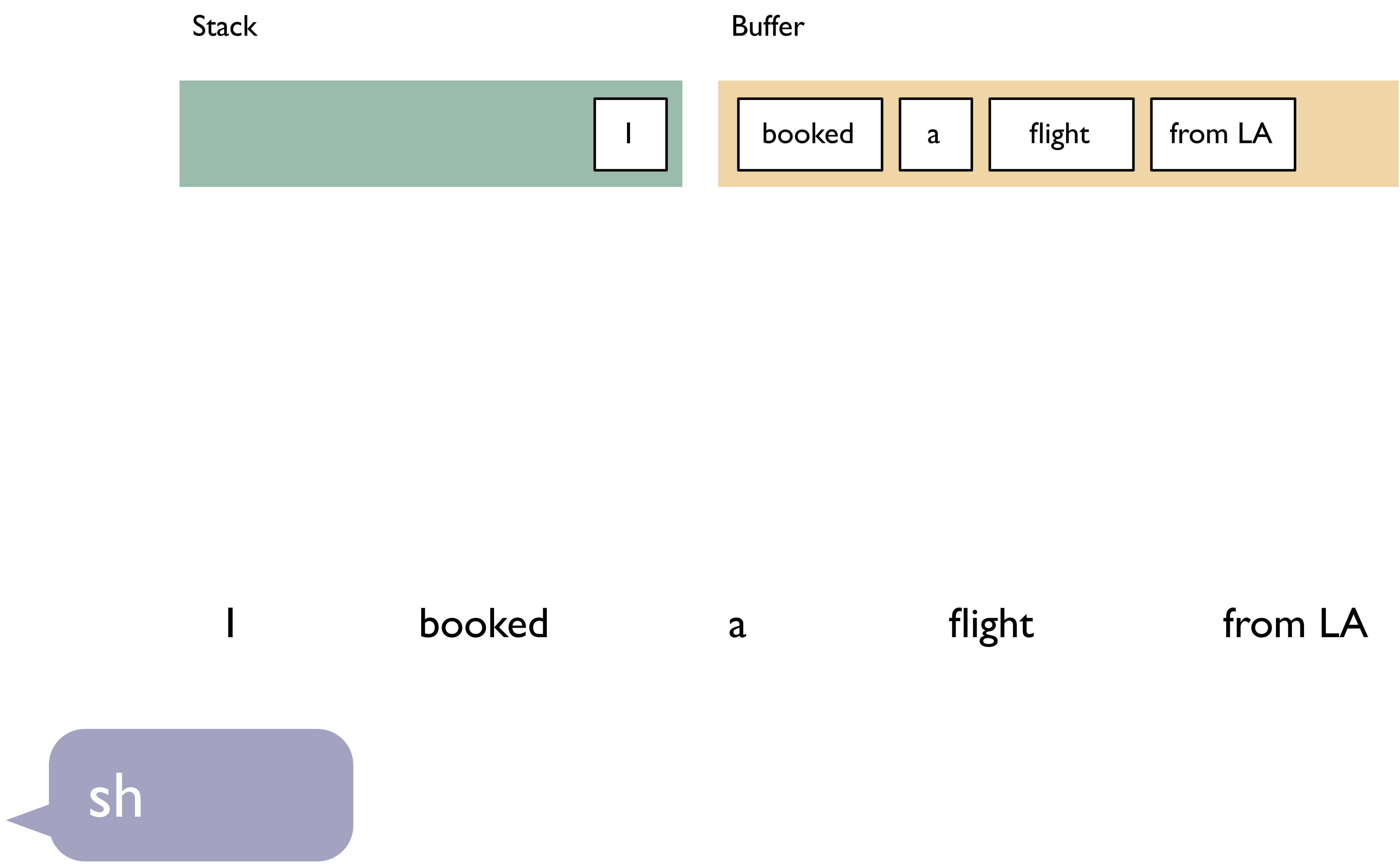
Example run



Example run


Stack
Buffer
I
booked
a
flight
from LA
I
booked
a
flight
from LA
sh

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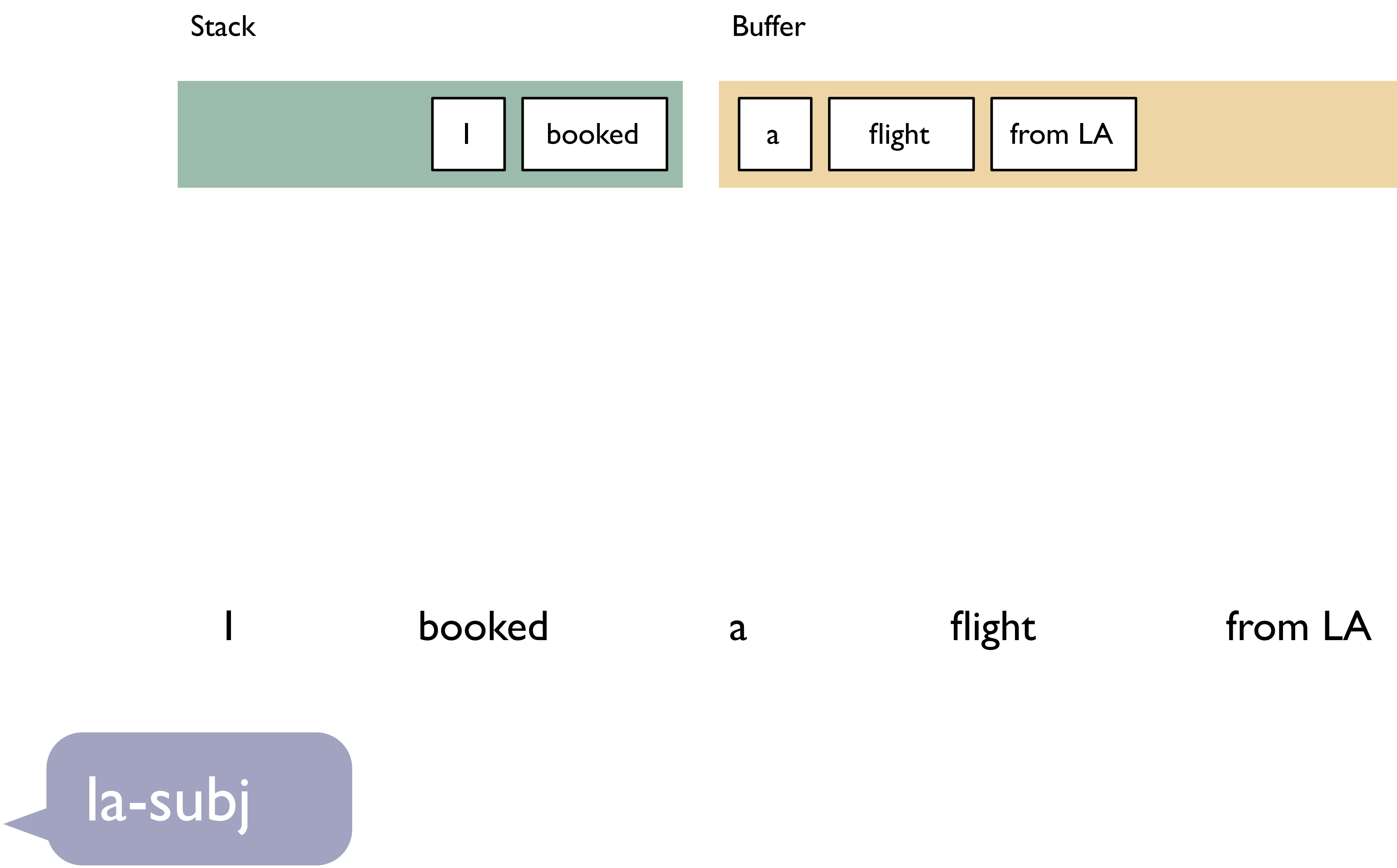
Example run



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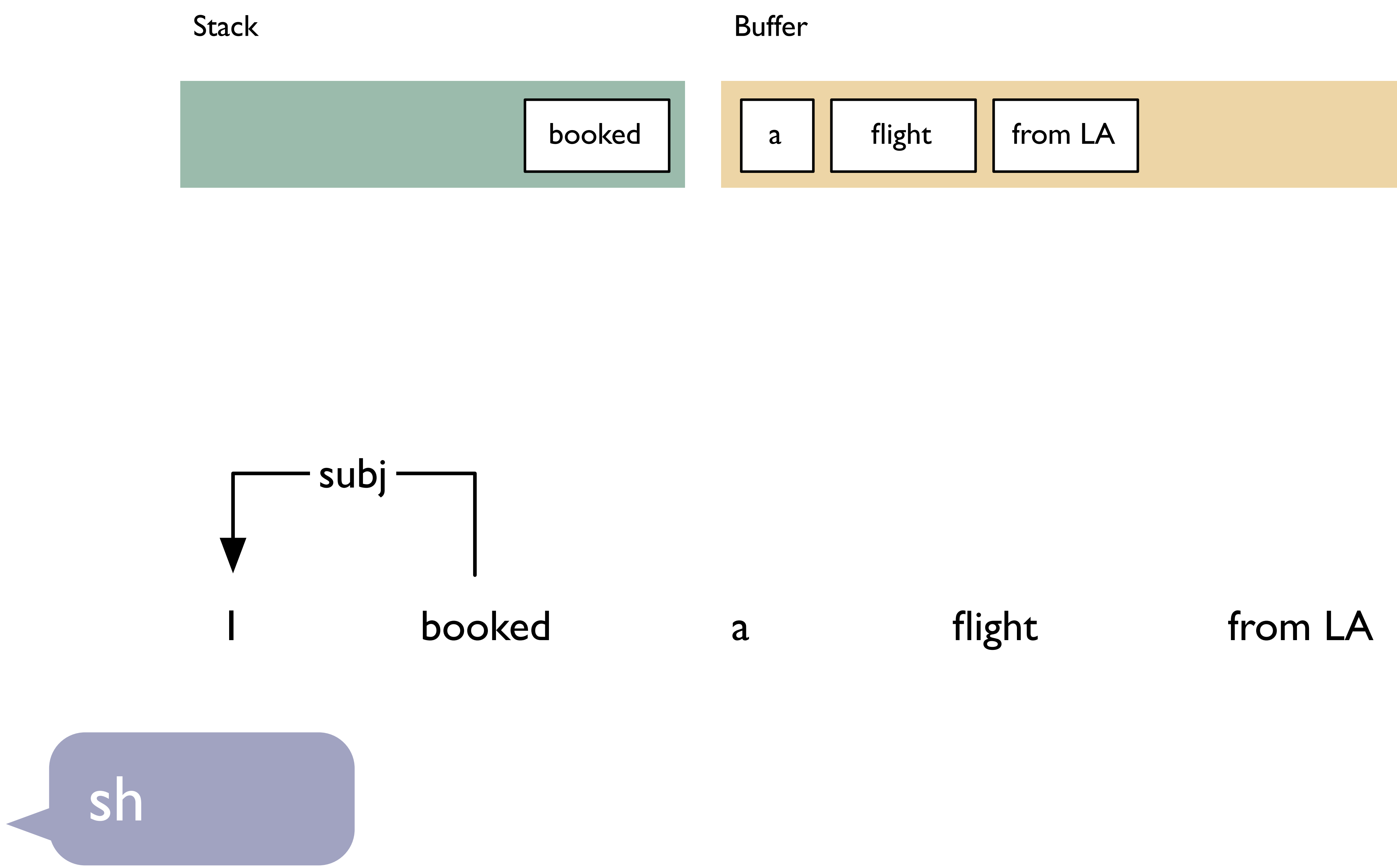
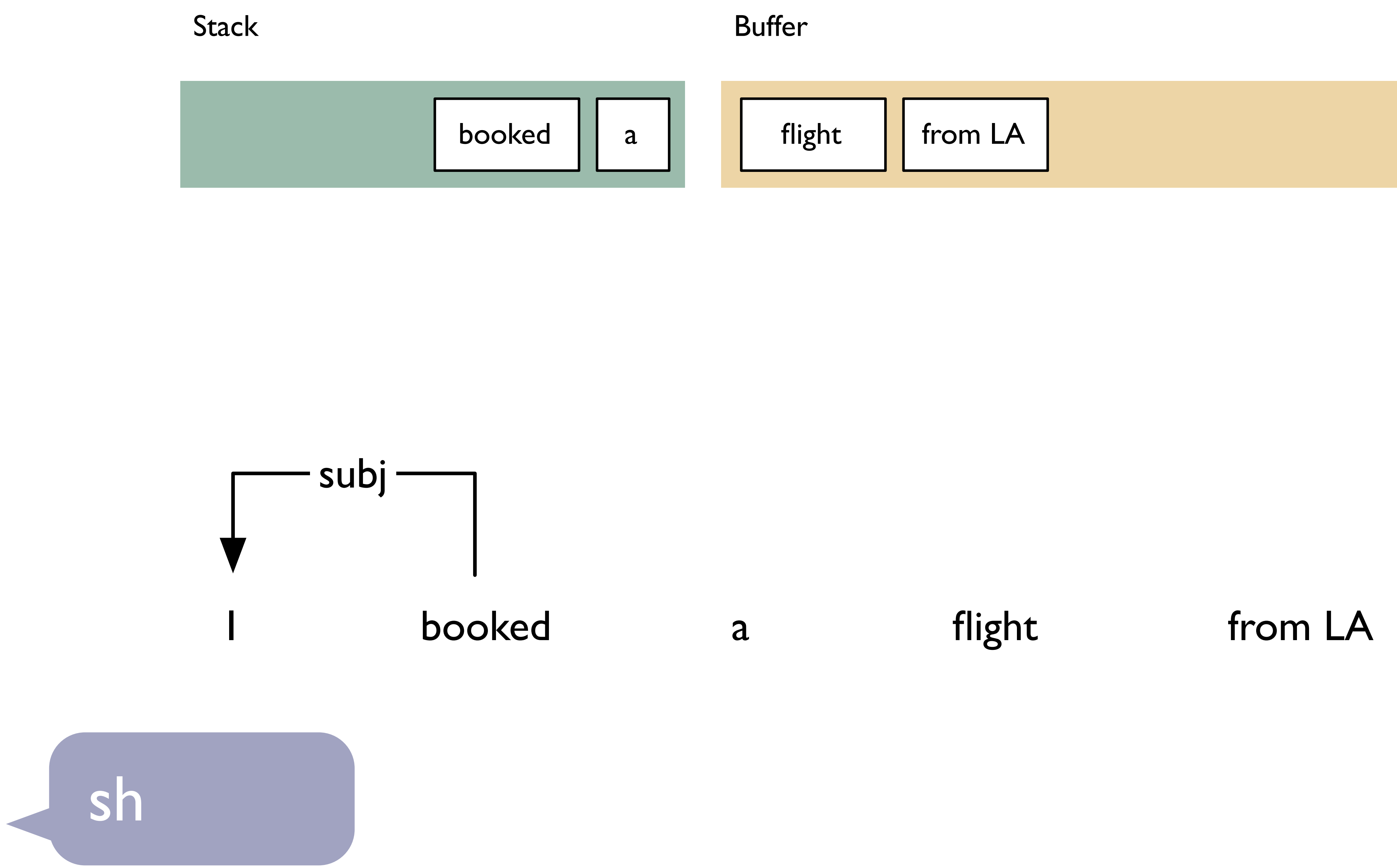
The arc-standard algorithm

Example run



Example run


Stack
booked
a
Buffer
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from LA
subj
I
booked
a
flight
from LA
sh

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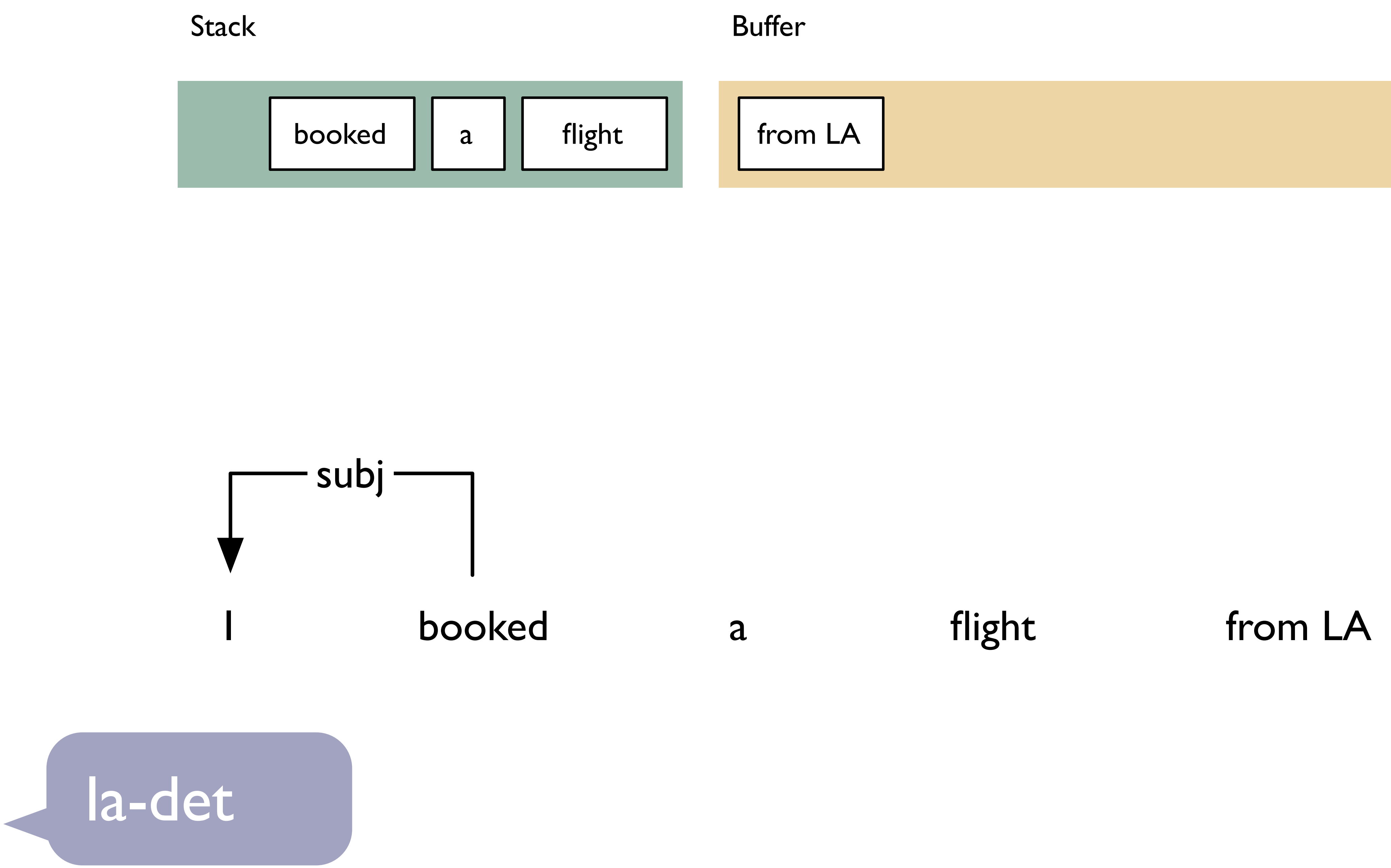
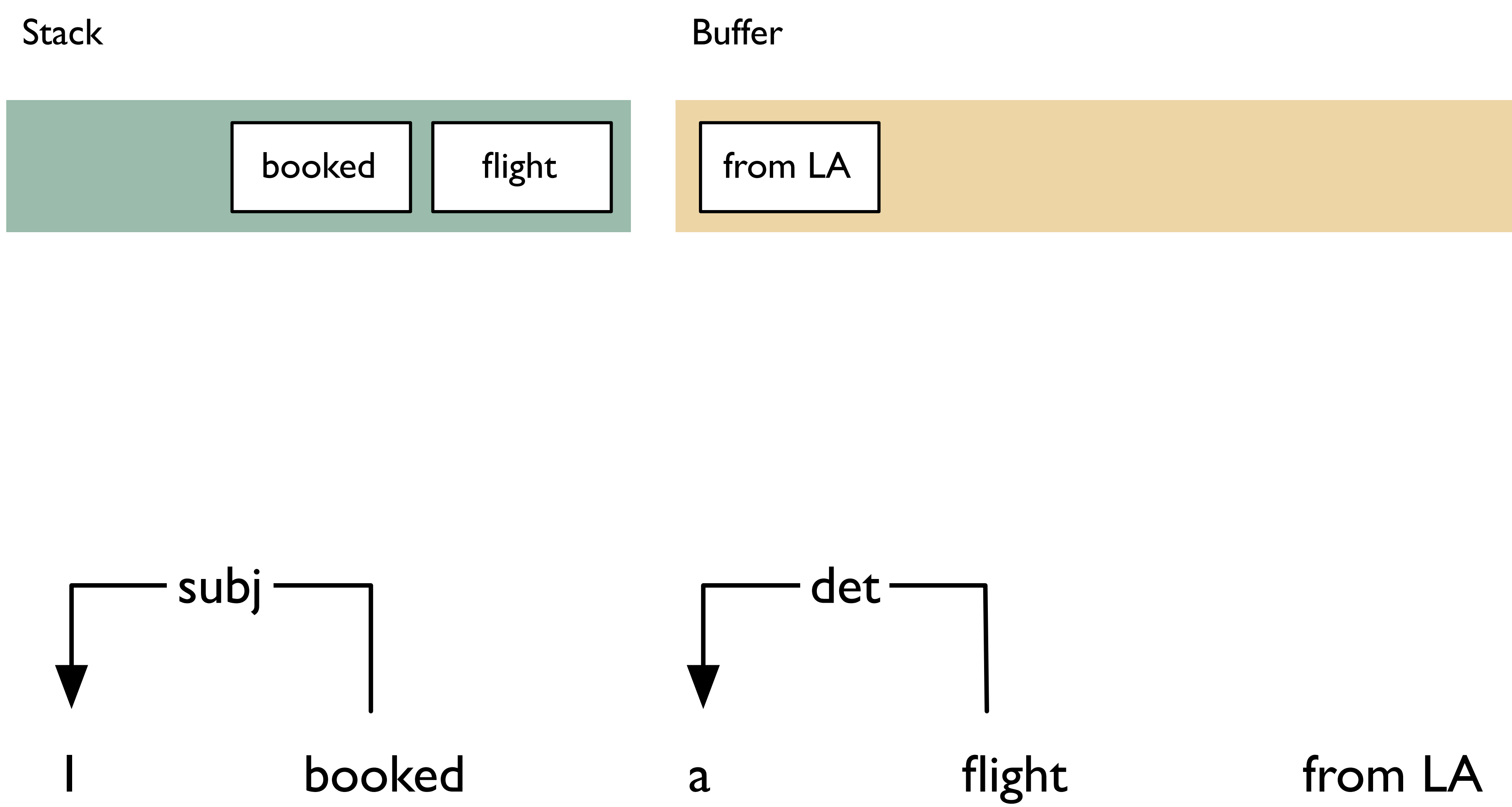
Example run



The arc-standard algorithm

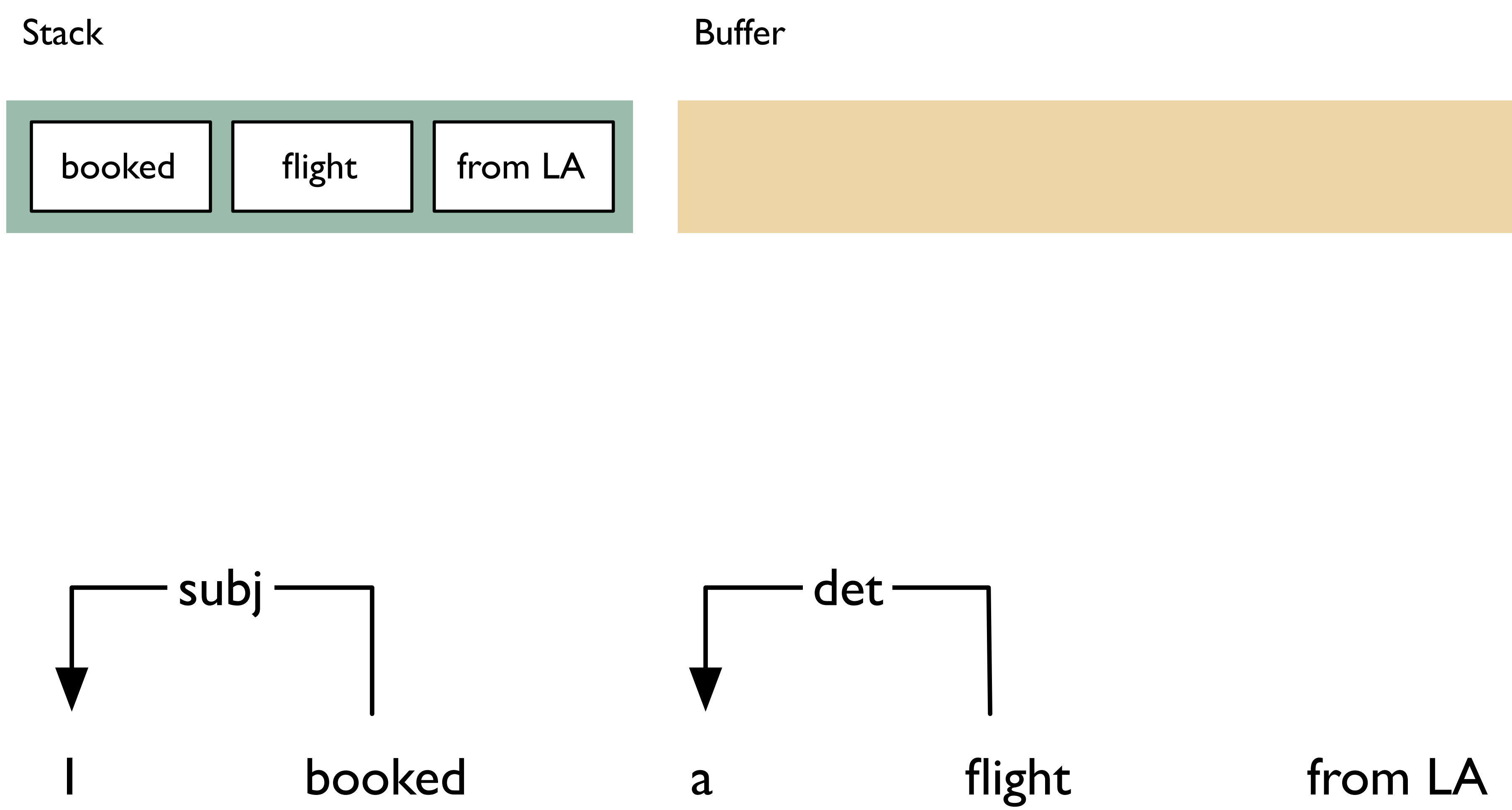
Example run



sh

The arc-standard algorithm

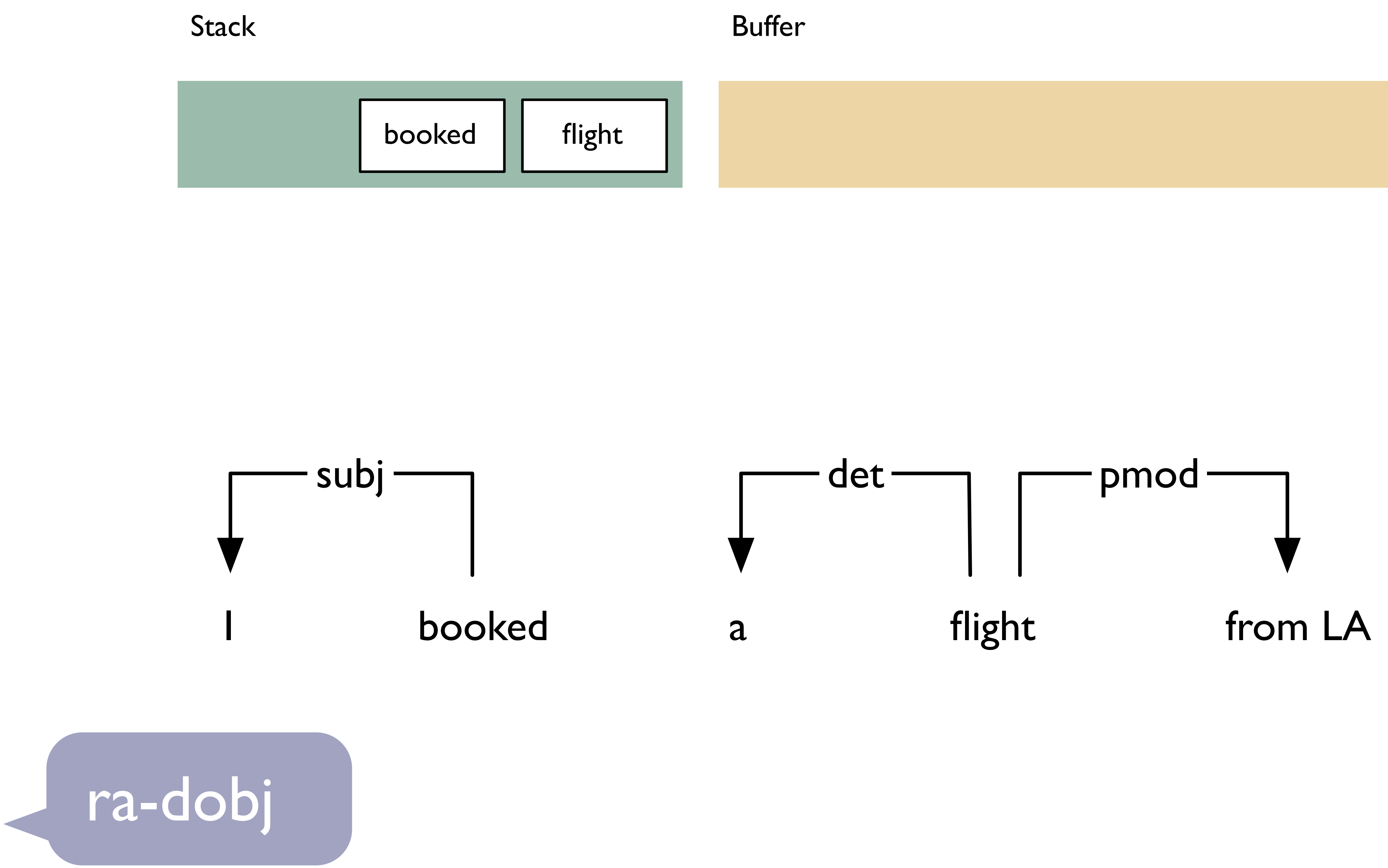
Example run



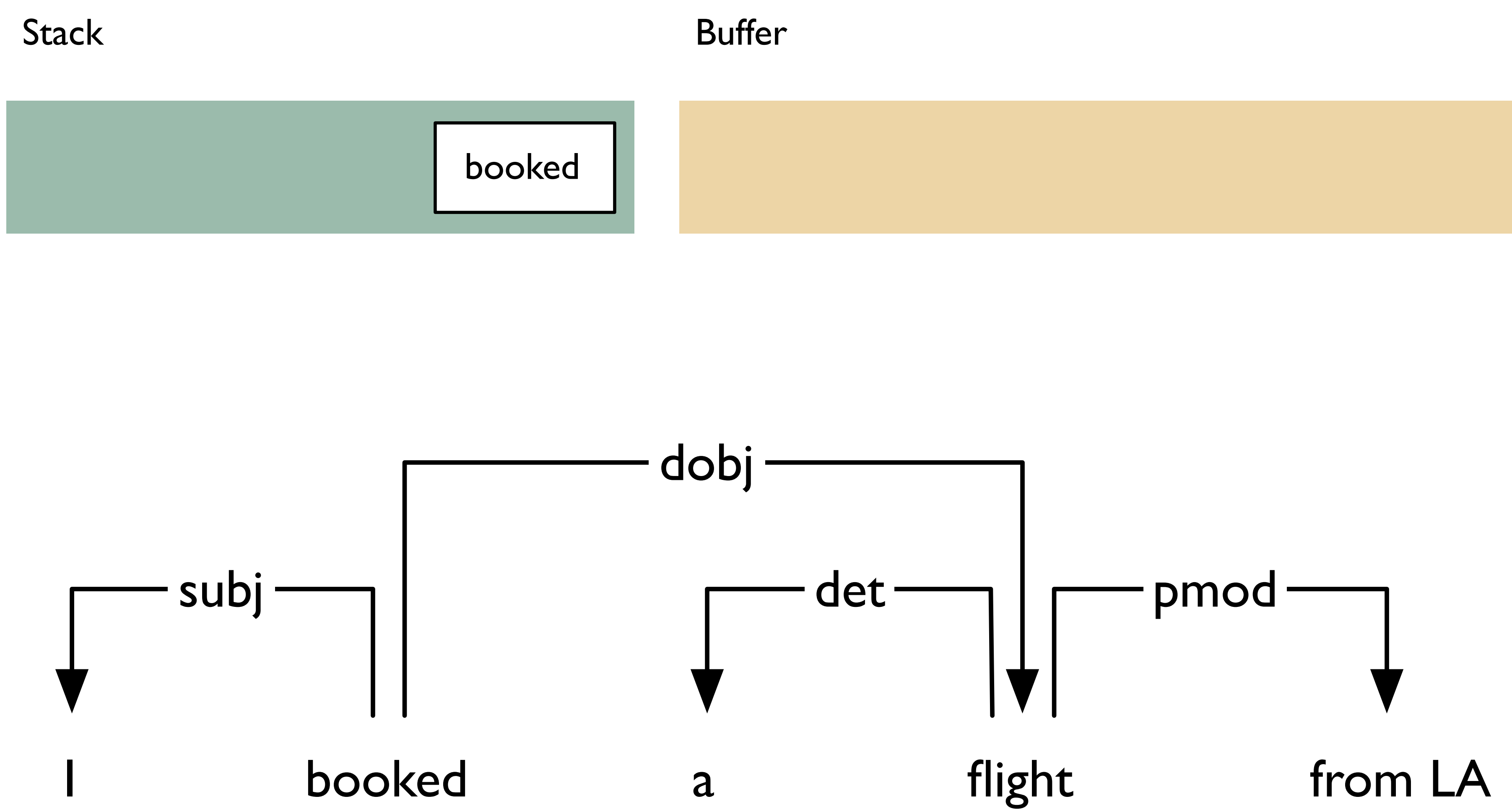
ra-pmod

The arc-standard algorithm

Example run



Example run



done!

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Evaluation of dependency parsing

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Evaluation of dependency parsers

- labelled attachment score:
  percentage of correct arcs,
  relative to the gold standard
- labelled exact match:
  percentage of correct dependency trees,
  relative to the gold standard
- unlabelled attachment score/exact match:
  the same, but ignoring arc labels

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Word- vs sentence-level evaluation

- Example: 2 sentence corpus
  sentence 1: 9/10 arcs correct
  sentence 2: 15/45 arcs correct
- Word-level (*micro-average*):
  (9+15)/(10+45) = 24/55 = 0.436
- Sentence-level (*macro-average*):
  (9/10+15/45)/2 = (0.9+0.33)/2 = 0.617

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Projectivity

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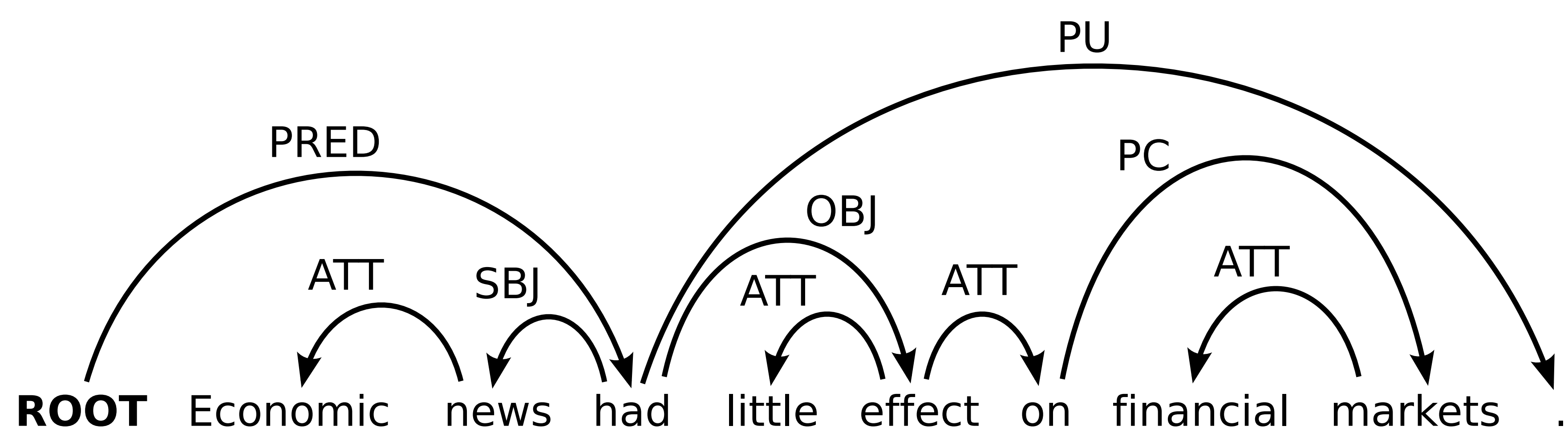
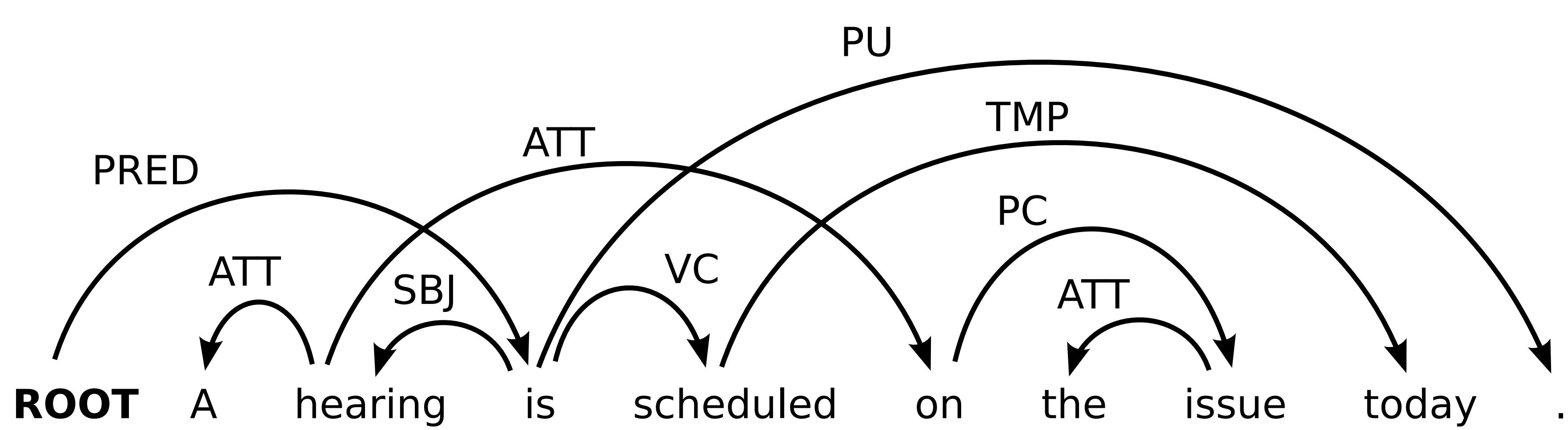
Projectivity

- A dependency tree is projective if:
  - For every arc in the tree, there is a directed path from the head of the arc to all words occurring between the head and the dependent (that is, the arc (i,l,j) implies that $i \rightarrow^* k$ for every k such that $\min(i, j) < k < \max(i, j)$)

Projective and non-projective trees





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Projectivity and dependency parsing

- Many dependency parsing algorithms can only handle projective trees
  - Including all algorithms we have discussed
- Non-projective trees do occur in natural language
  - How often depends on language (and treebank)

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Non-projective dependency parsing

- Variants of transition-based parsing
  - Using a swap-transition
  - Pseudo-projective parsing
- Graph-based parsing
  - Minimum spanning tree algorithms
- . . .

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Summary

- In transition-based dependency parsing one does not score graphs but computations, sequences of (configuration, transition) pairs.
- In its simplest form, transition-based dependency parsing uses classification.
- One specific instance of transition-based dependency parsing is the arc-standard algorithm.