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Transition-based dependency parsing

Syntactic analysis (5LN455)

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Based on slides from Marco Kuhlmann

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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

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.

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.

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.

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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 $w = w_1 \dots w_n$ consists of three components:

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

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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

Configurations and transitions

- Initial configuration: ([],[0,...,n],[])
- Terminal configuration: ([0],[],A)
- shift (sh):

  $(\sigma,[i|\beta],A) \Rightarrow ([\sigma|i],\beta,A)$

- left-arc (la):

  $([\sigma|i|j],B,A) \Rightarrow ([\sigma|j],B,A\cup\{j,l,i\})$ only if $i \neq 0$

- right-arc (ra):

  $([\sigma|i|j],B,A) \Rightarrow ([\sigma|i],B,A\cup\{i,l,j\})$

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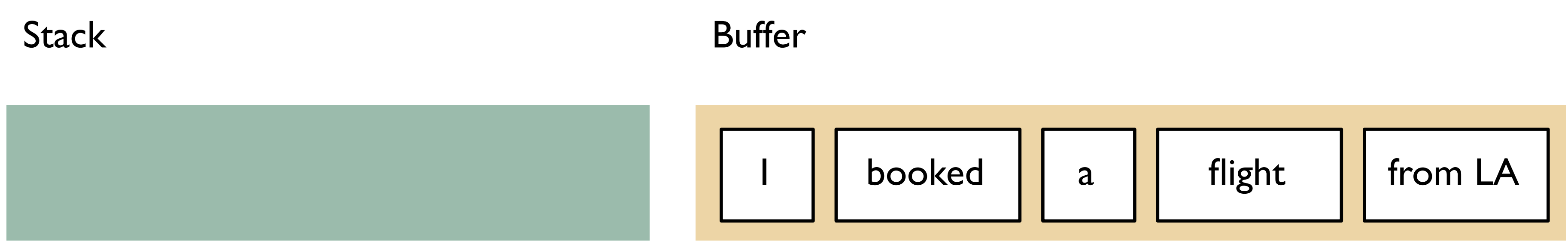
The arc-standard algorithm

Example run



I booked a flight from LA

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The arc-standard algorithm

Example run

Stack

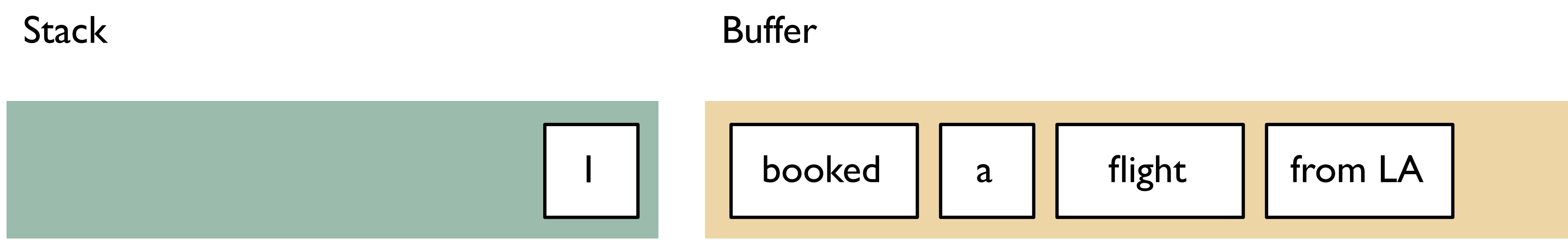
Buffer

I	booked	a	flight	from LA

I booked a flight from LA

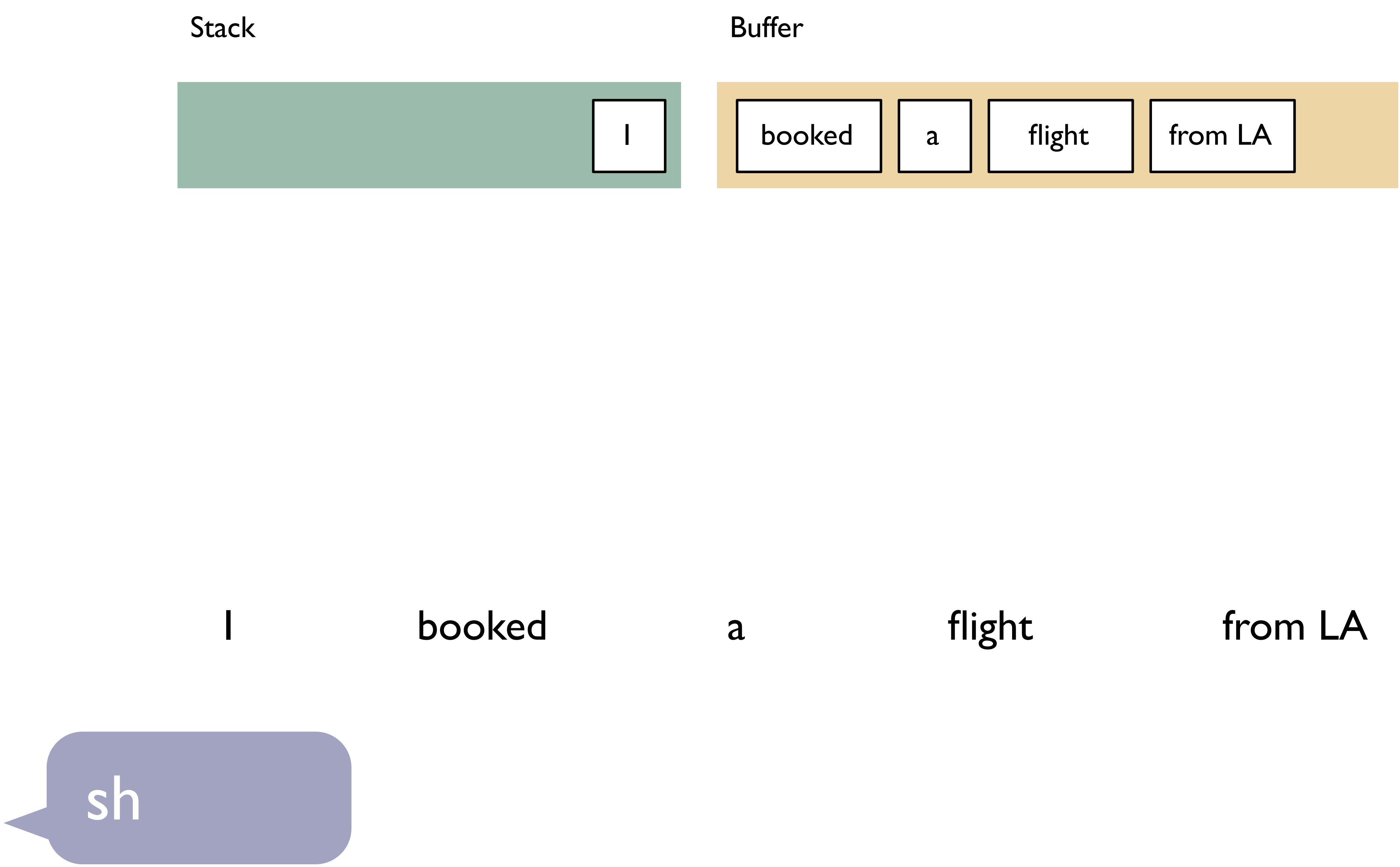
sh

Example run



I booked a flight from LA

Example run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from LA
sh

Example run

Stack

I	booked

Buffer

a	flight	from LA

I booked a flight from LA

Example run

Stack

I	booked

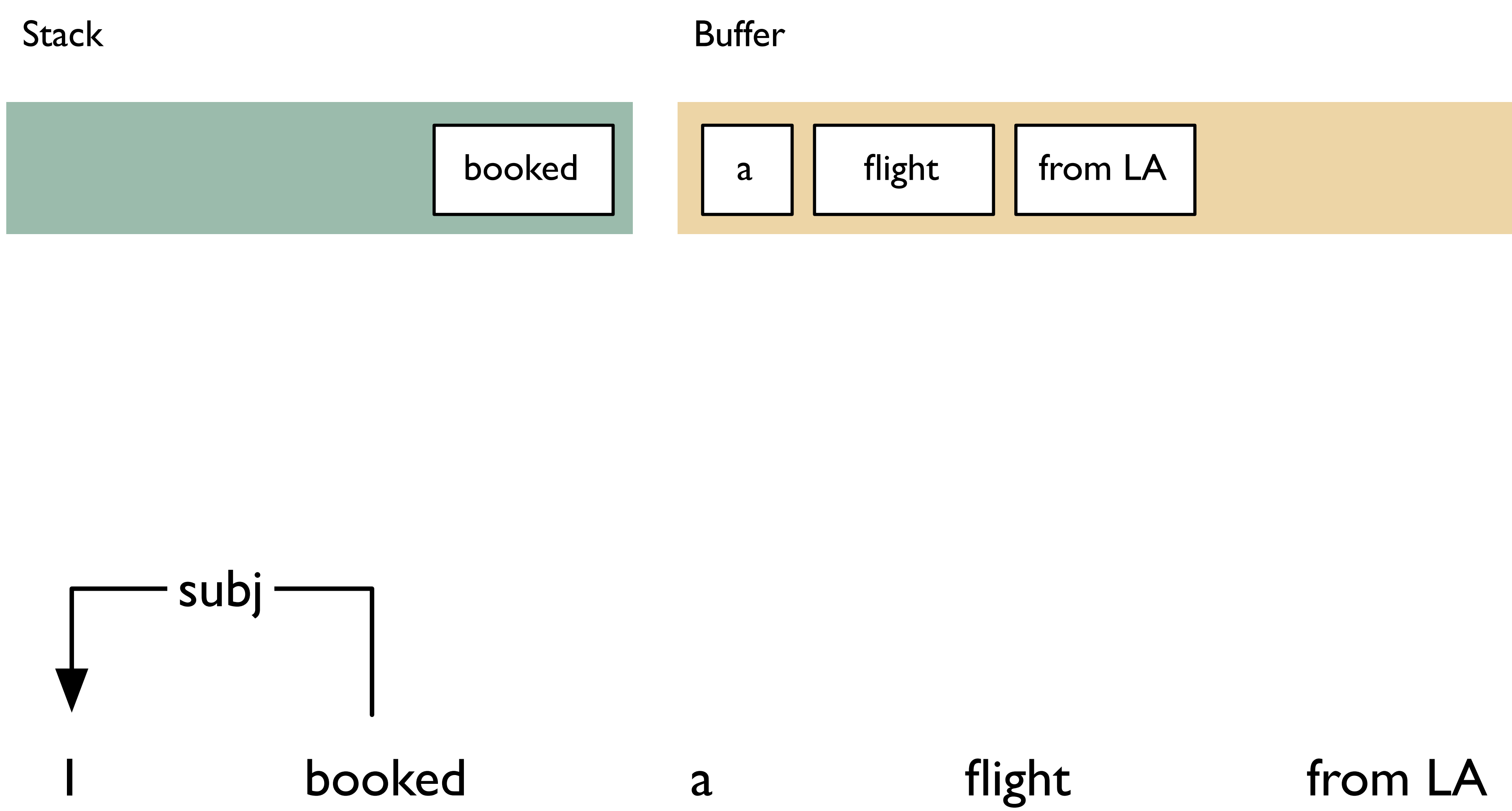
Buffer

a	flight	from LA

I booked a flight from LA

la-subj

Example run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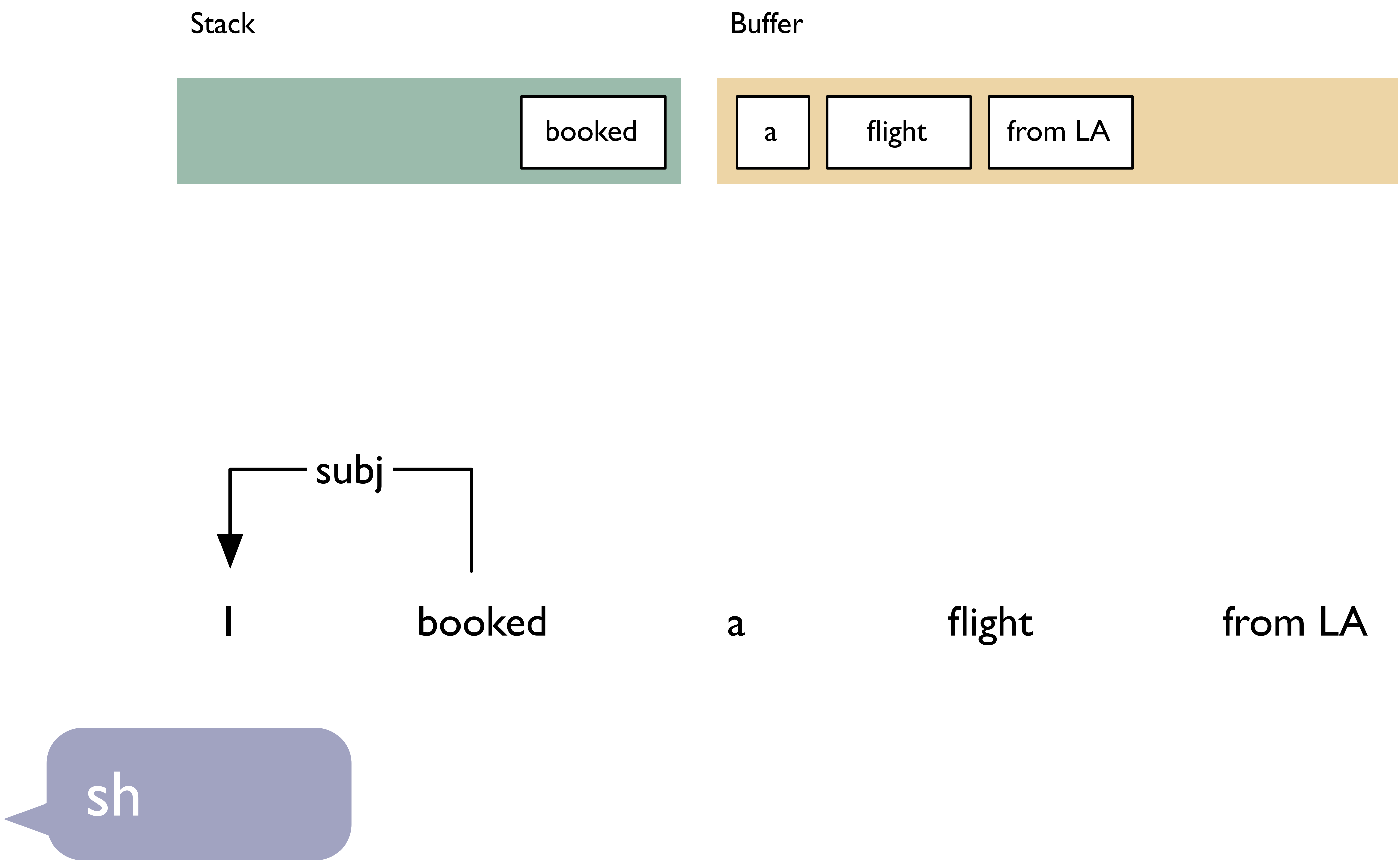
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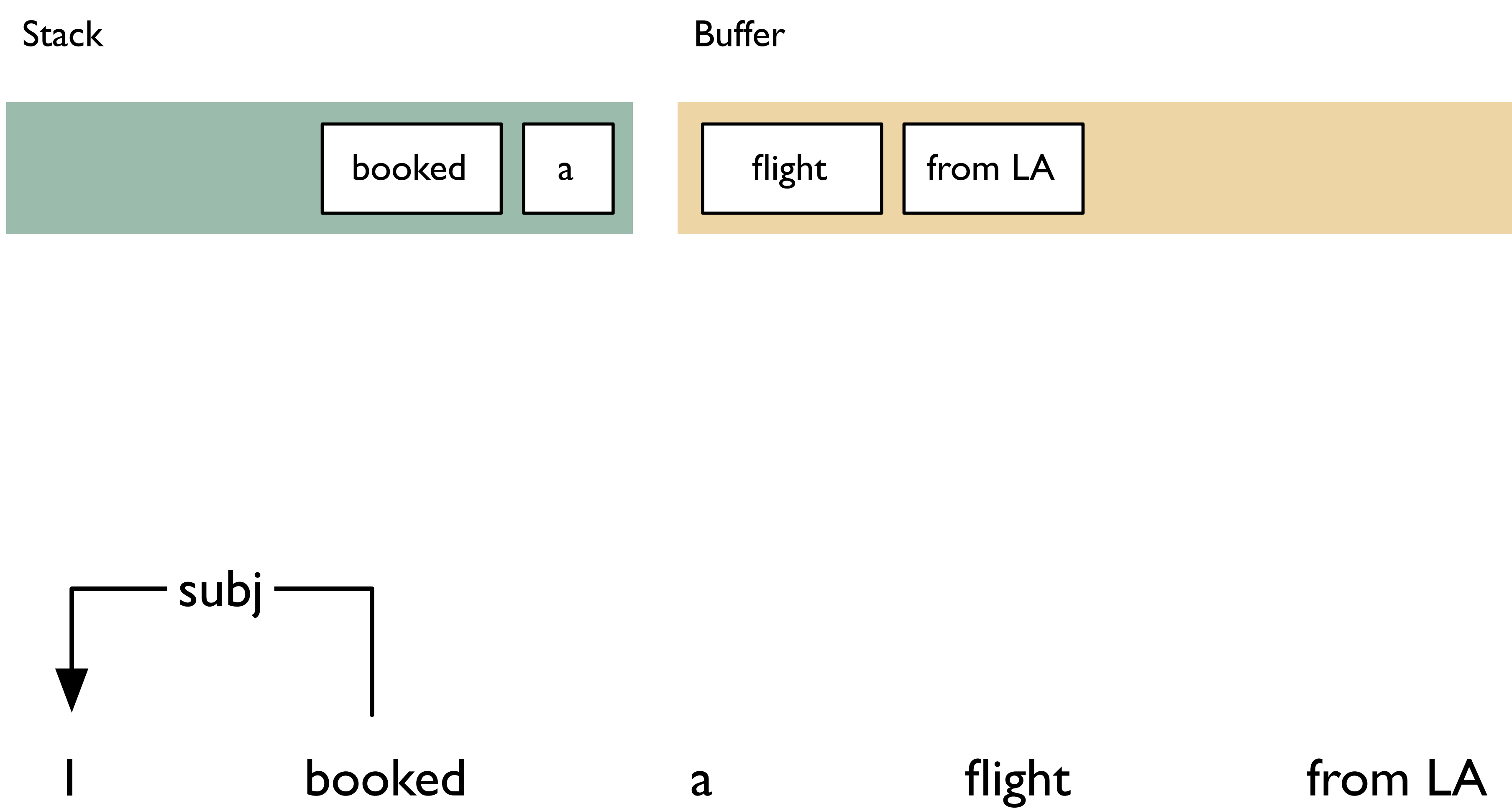
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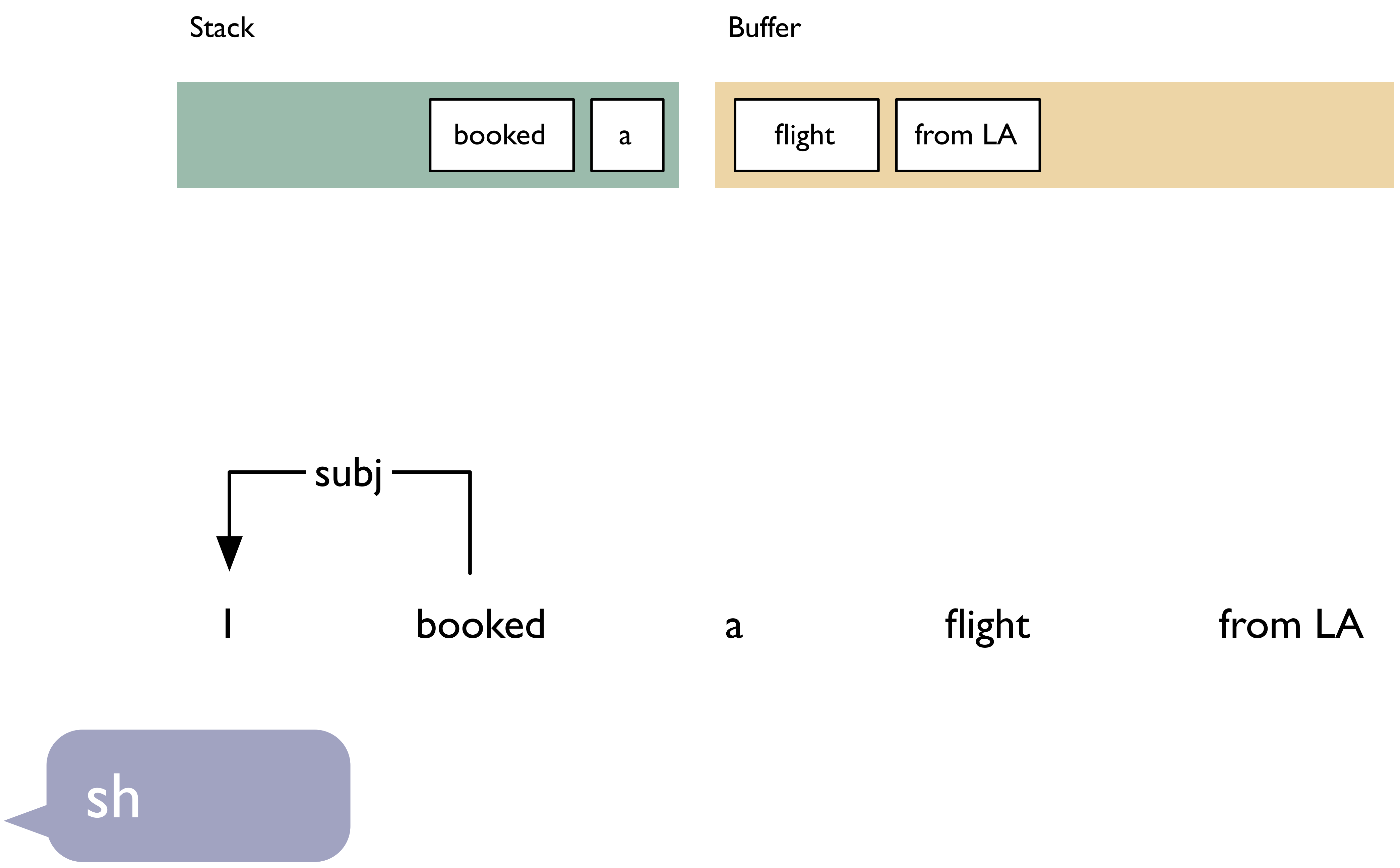
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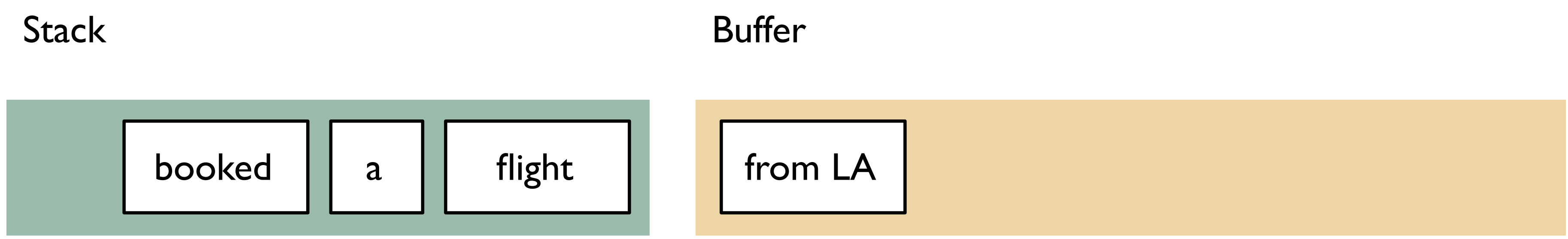
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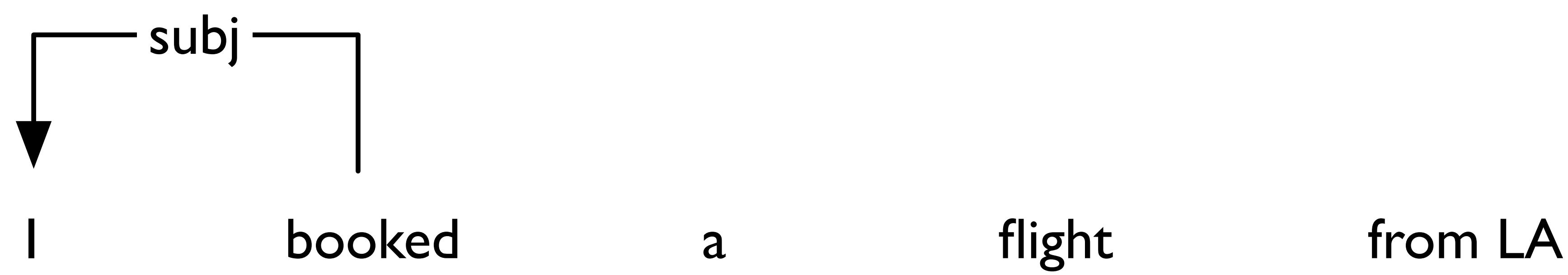
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The arc-standard algorithm

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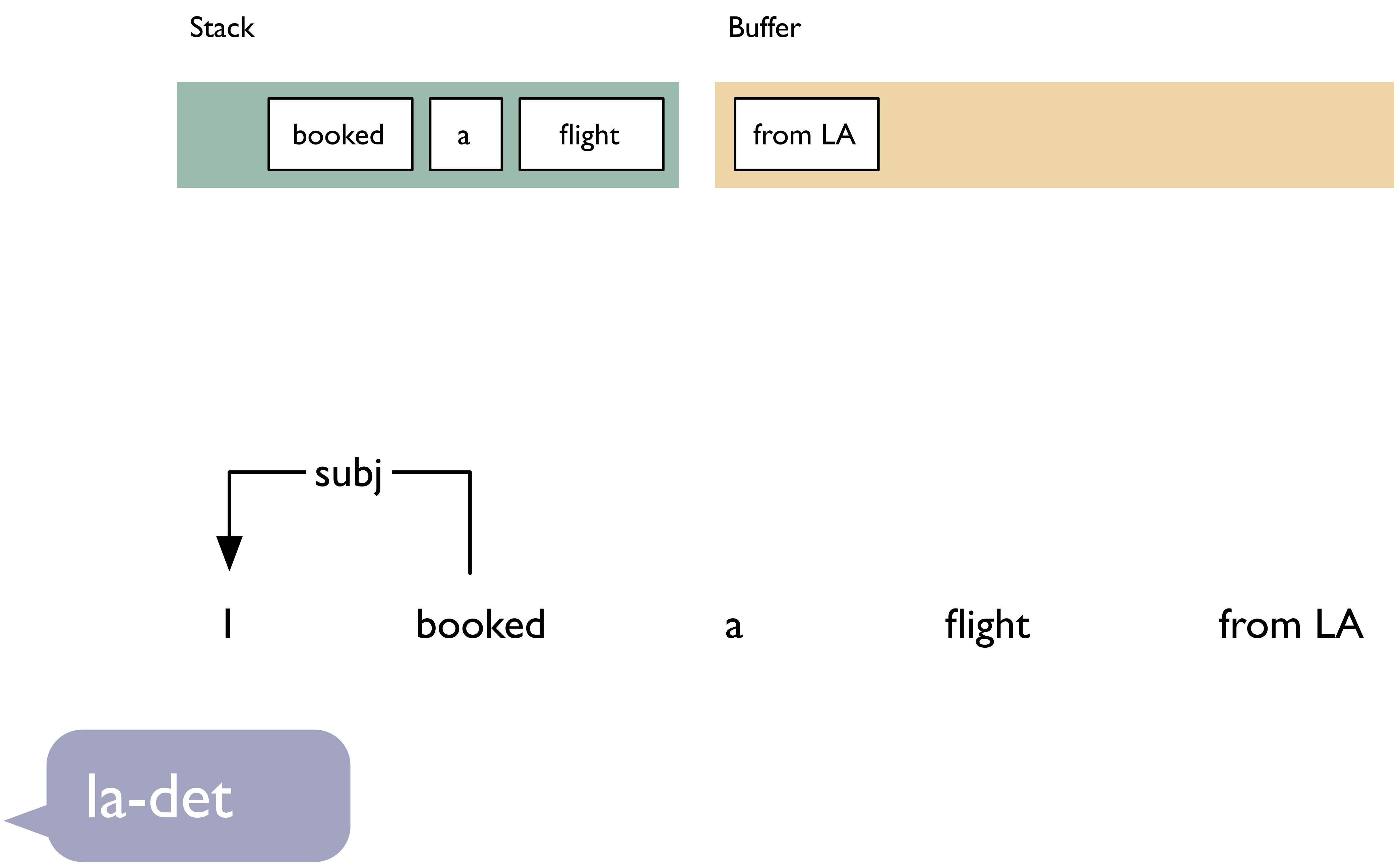

The arc-standard algorithm

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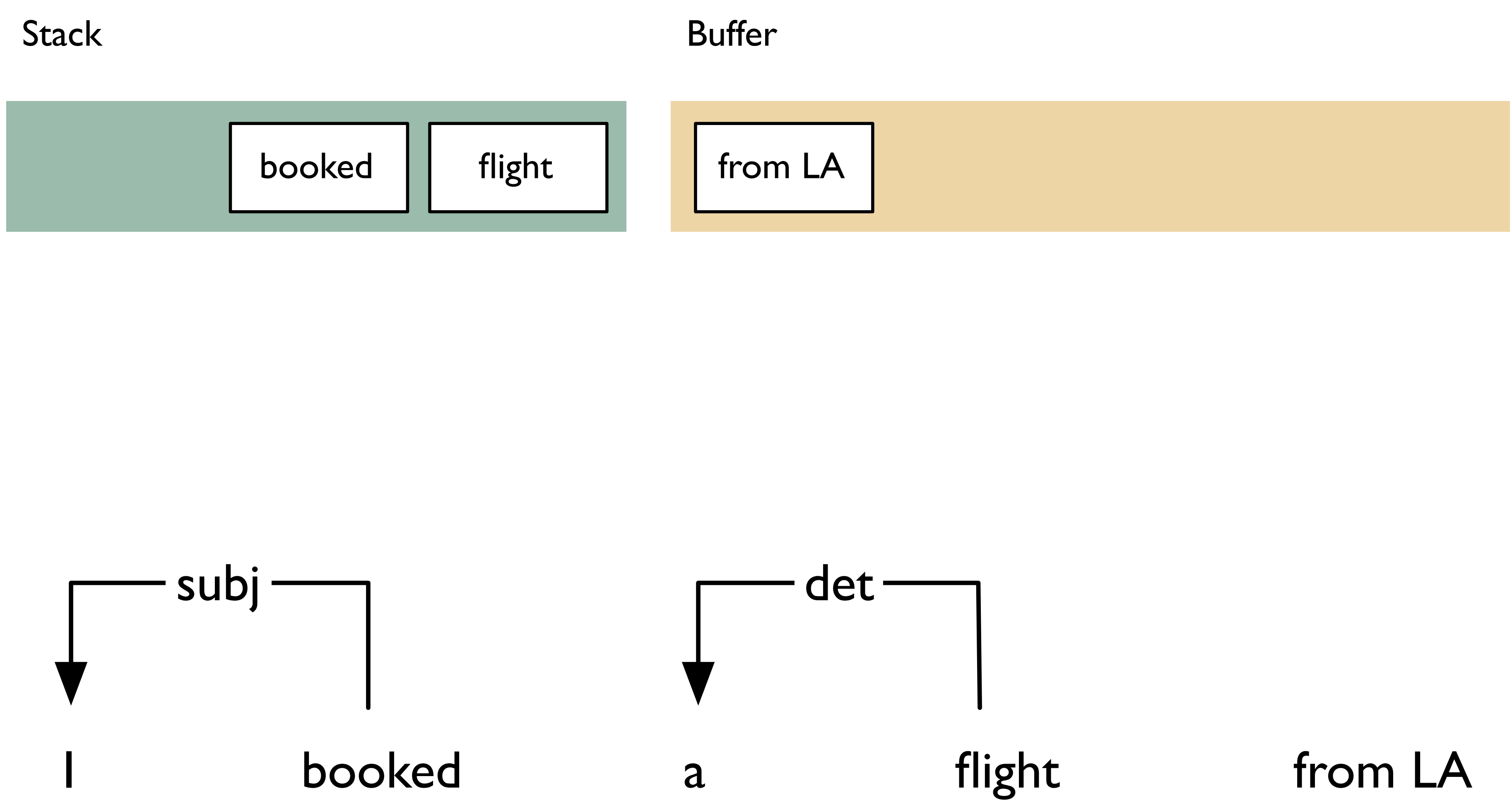

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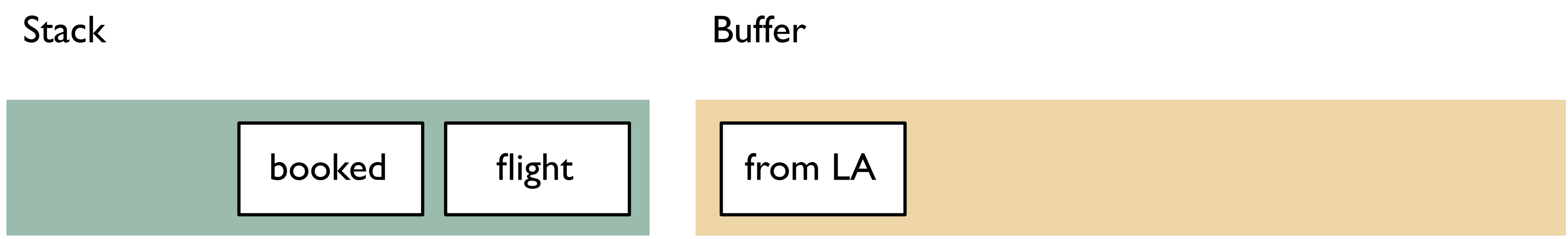
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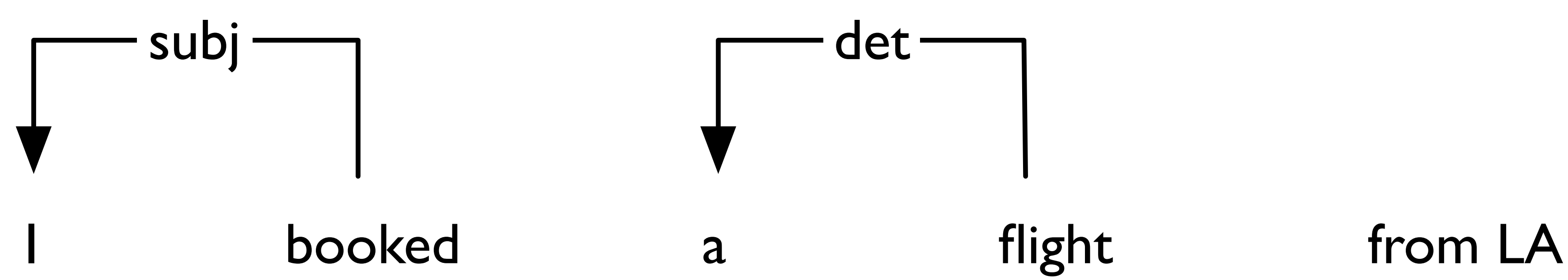
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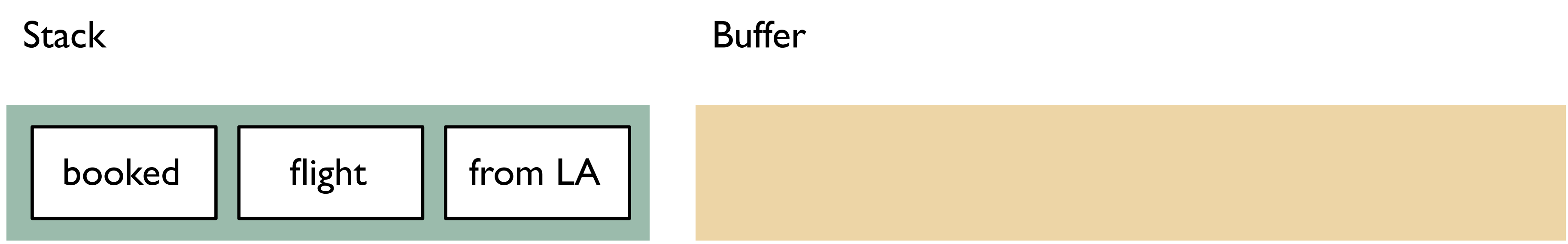
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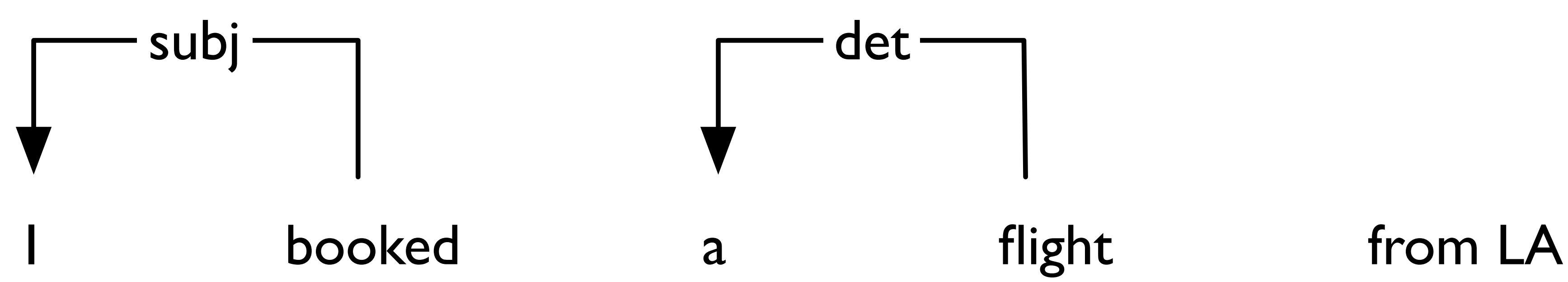
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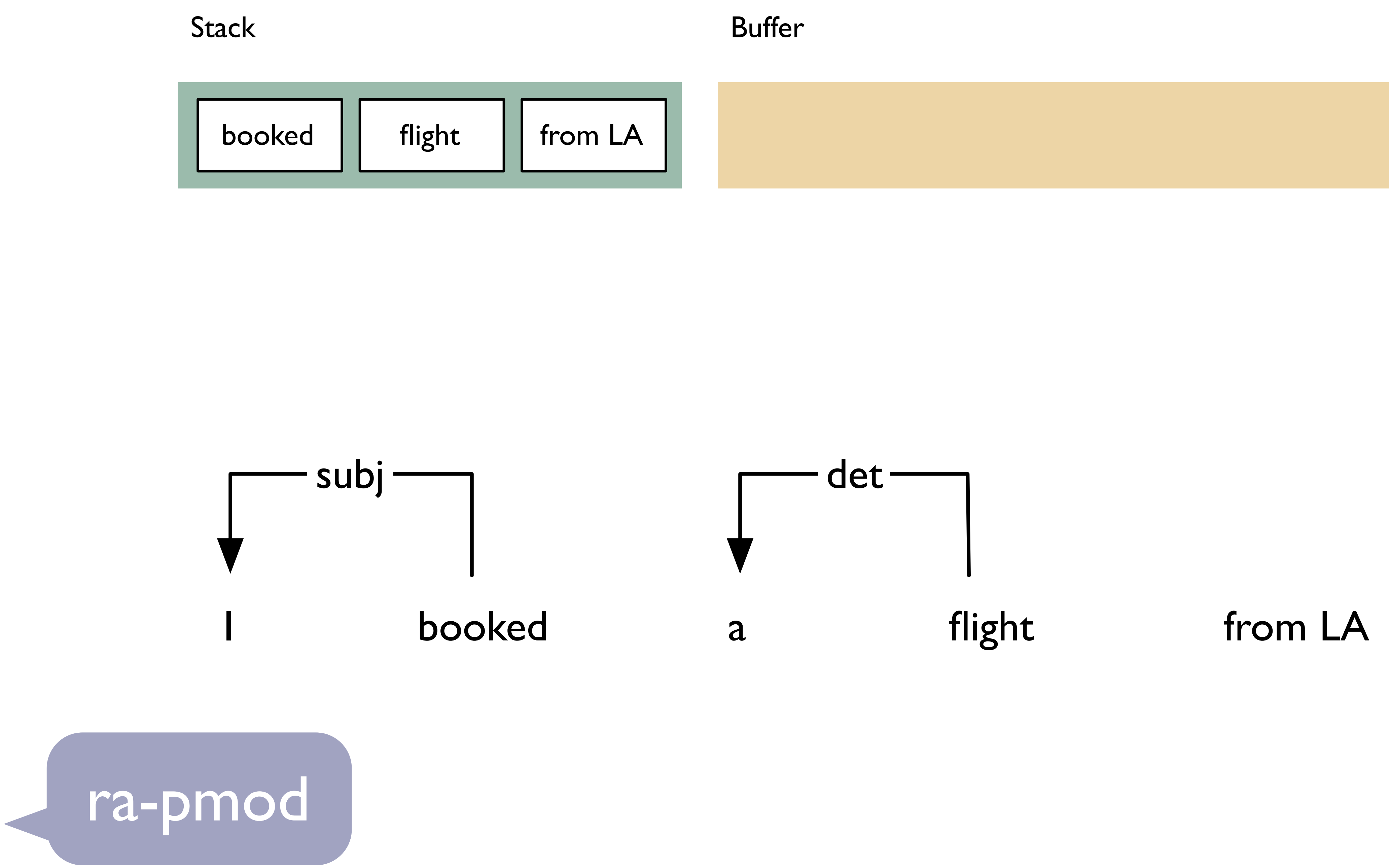
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The arc-standard algorithm

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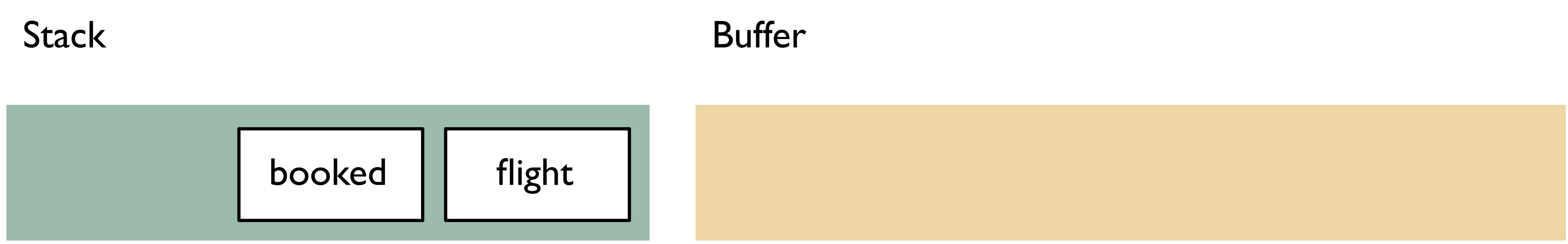

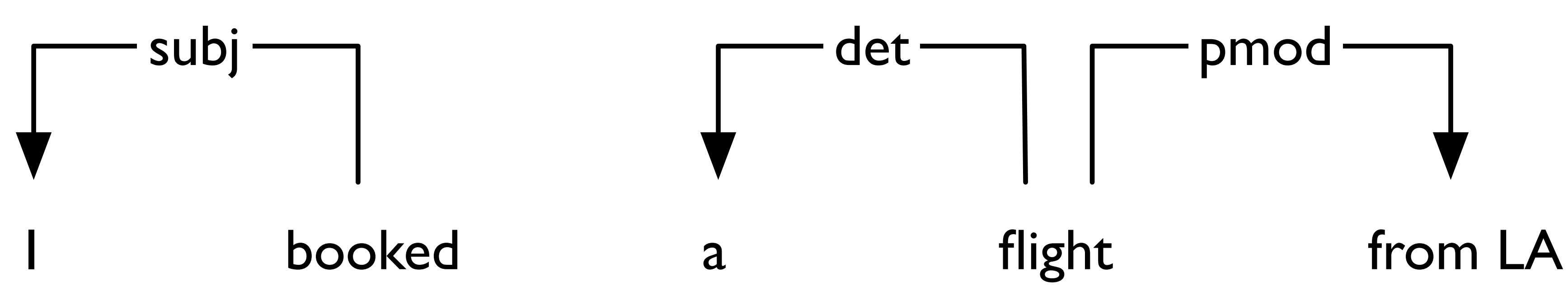

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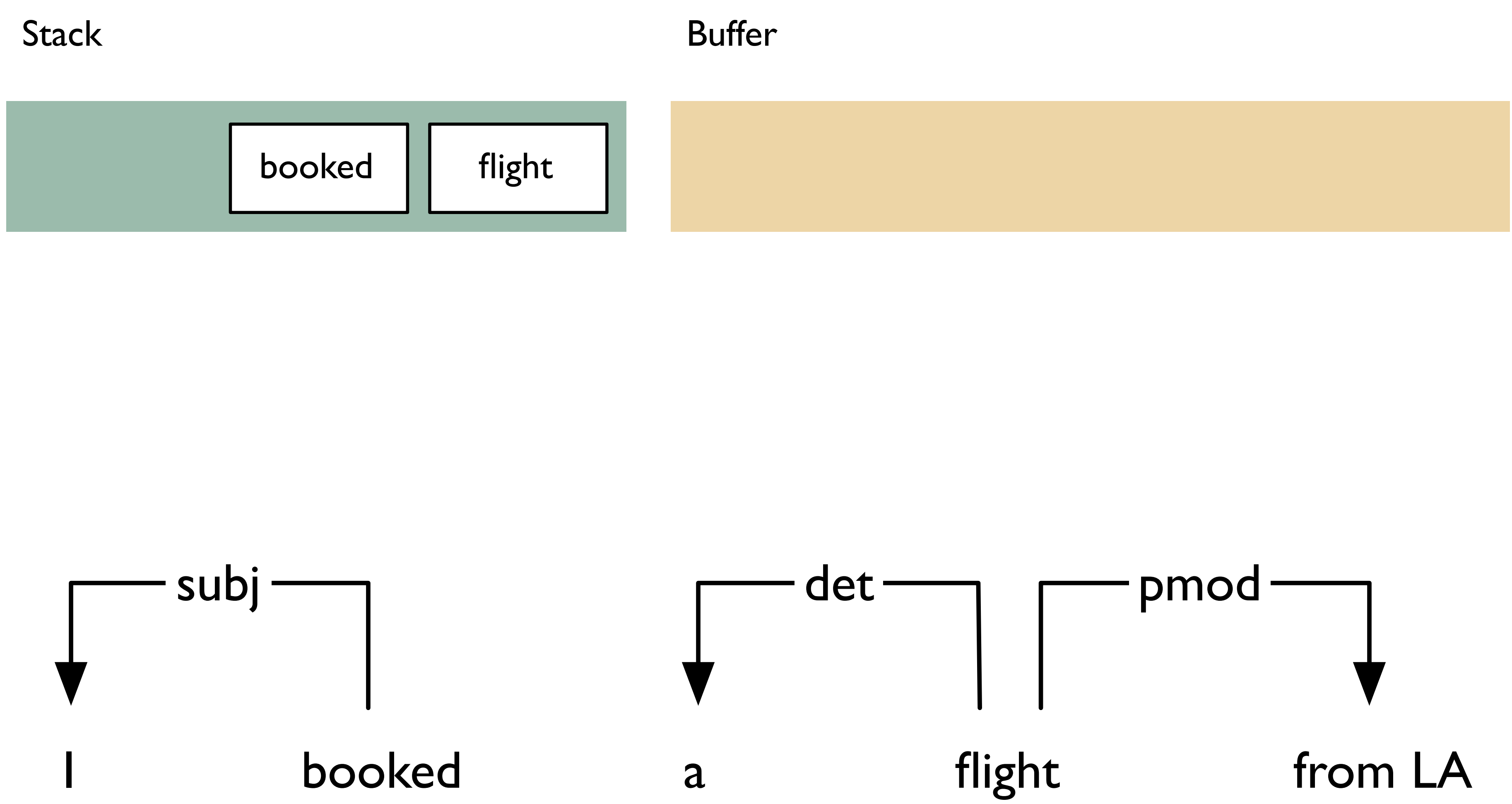

ra-dobj

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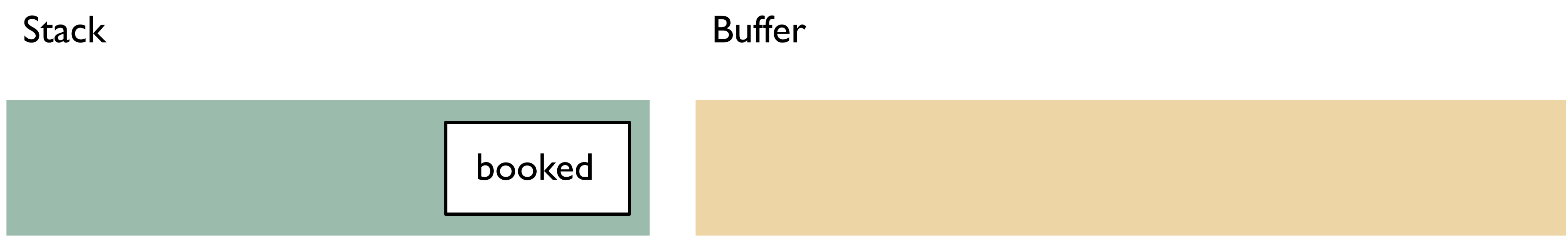
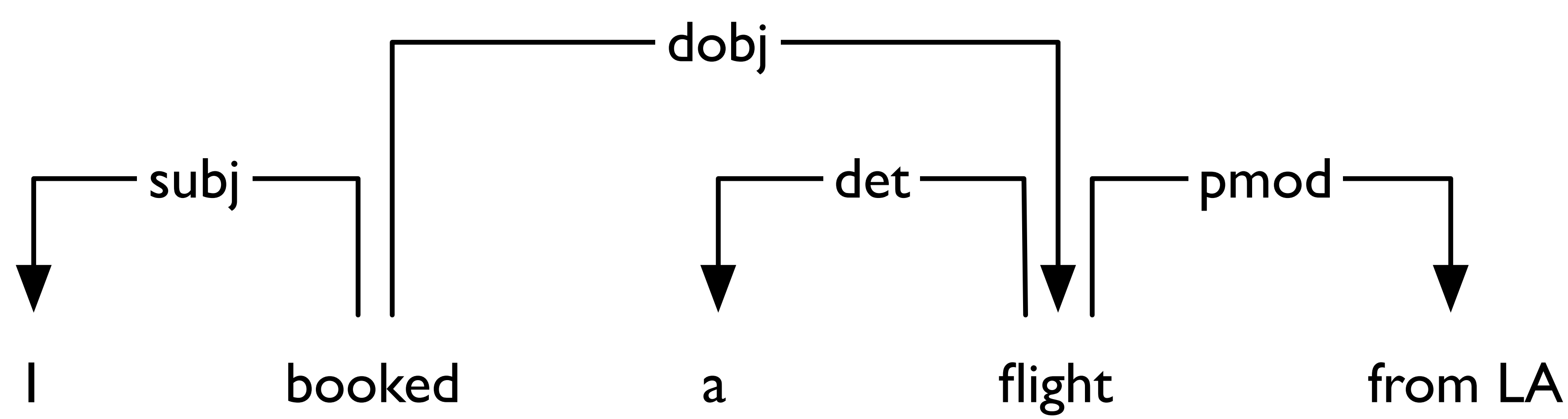
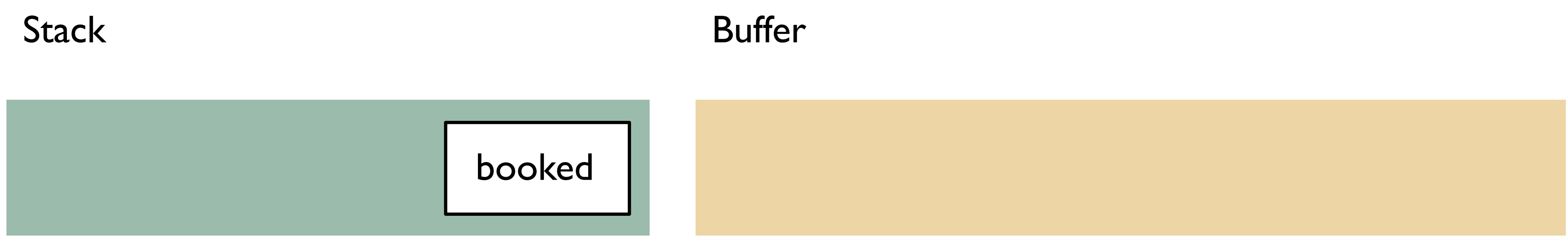
The arc-standard algorithm

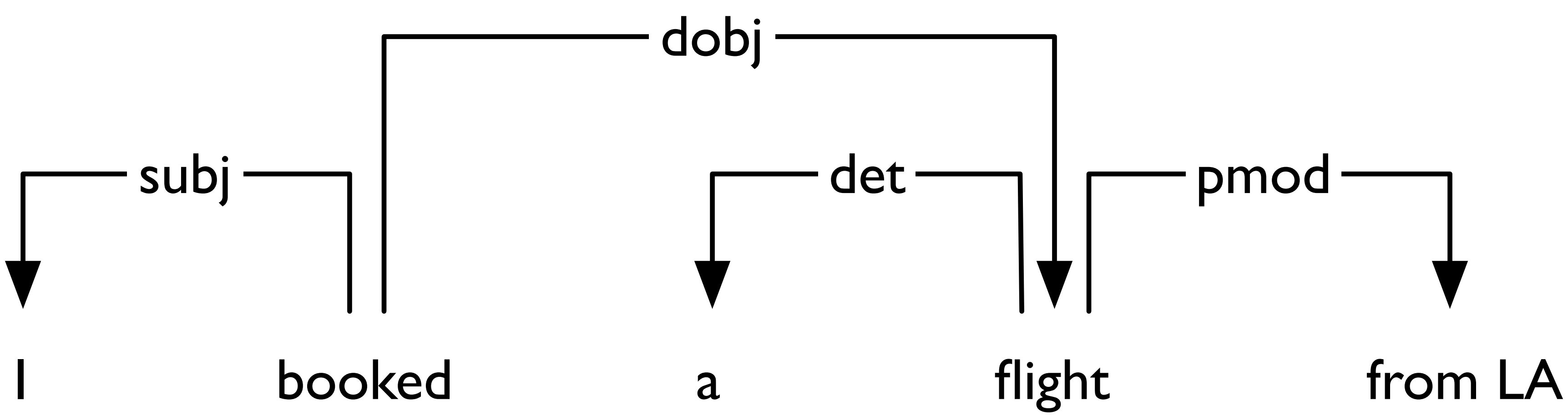
Example run





Example run





done!

Complexity and optimality

- Time complexity is linear, O(n), since we only have to treat each word once
- This can be achieved since the algorithm is greedy, and only builds one tree, in contrast to Eisner's algorithm, where all trees are explored
- There is no guarantee that we will even find the best tree given the model, with the arc-standard model
- There is a risk of error propagation
- An advantage is that we can use very informative features, for the ML algorithm

Training a guide

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.

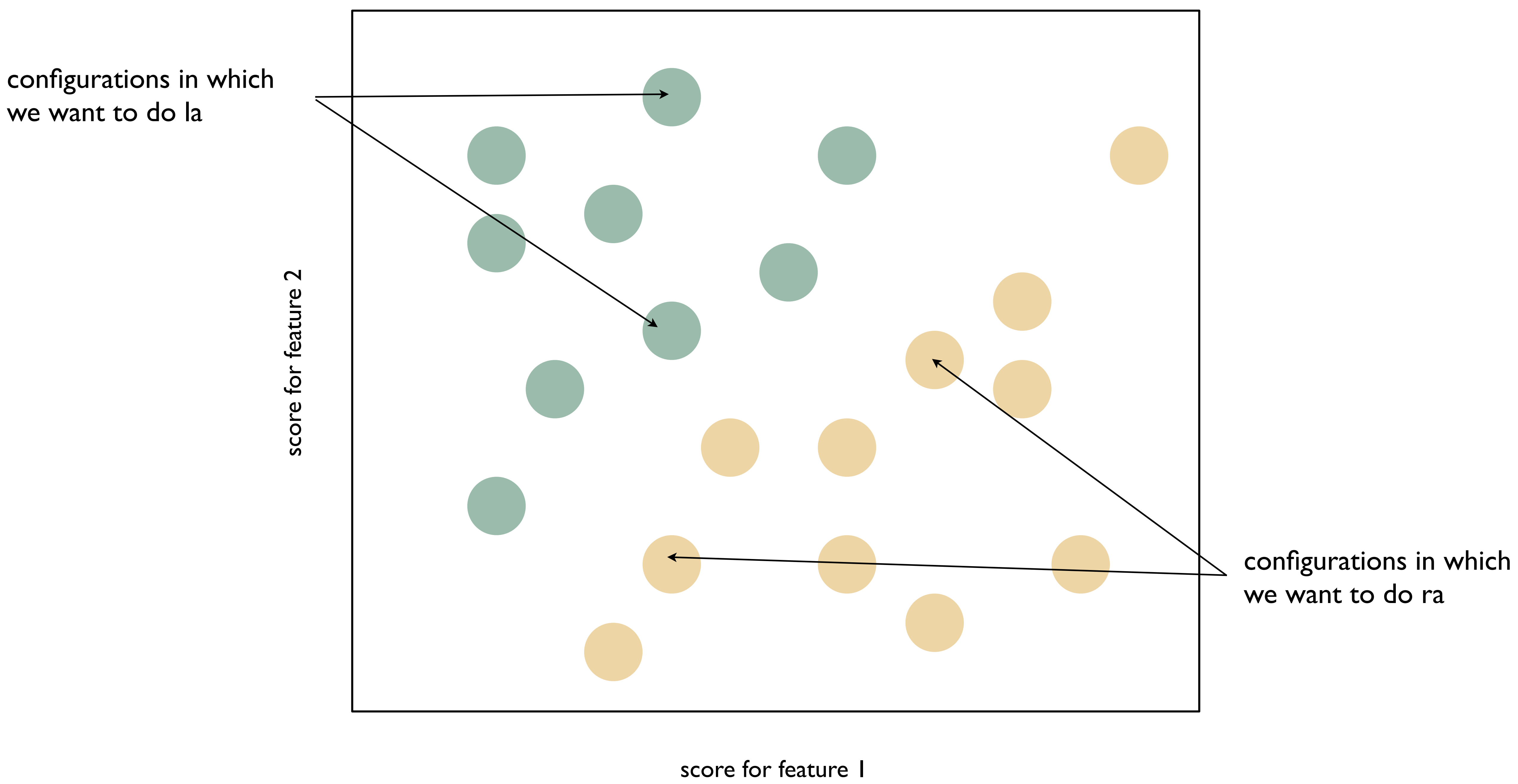
Training a guide

- 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.

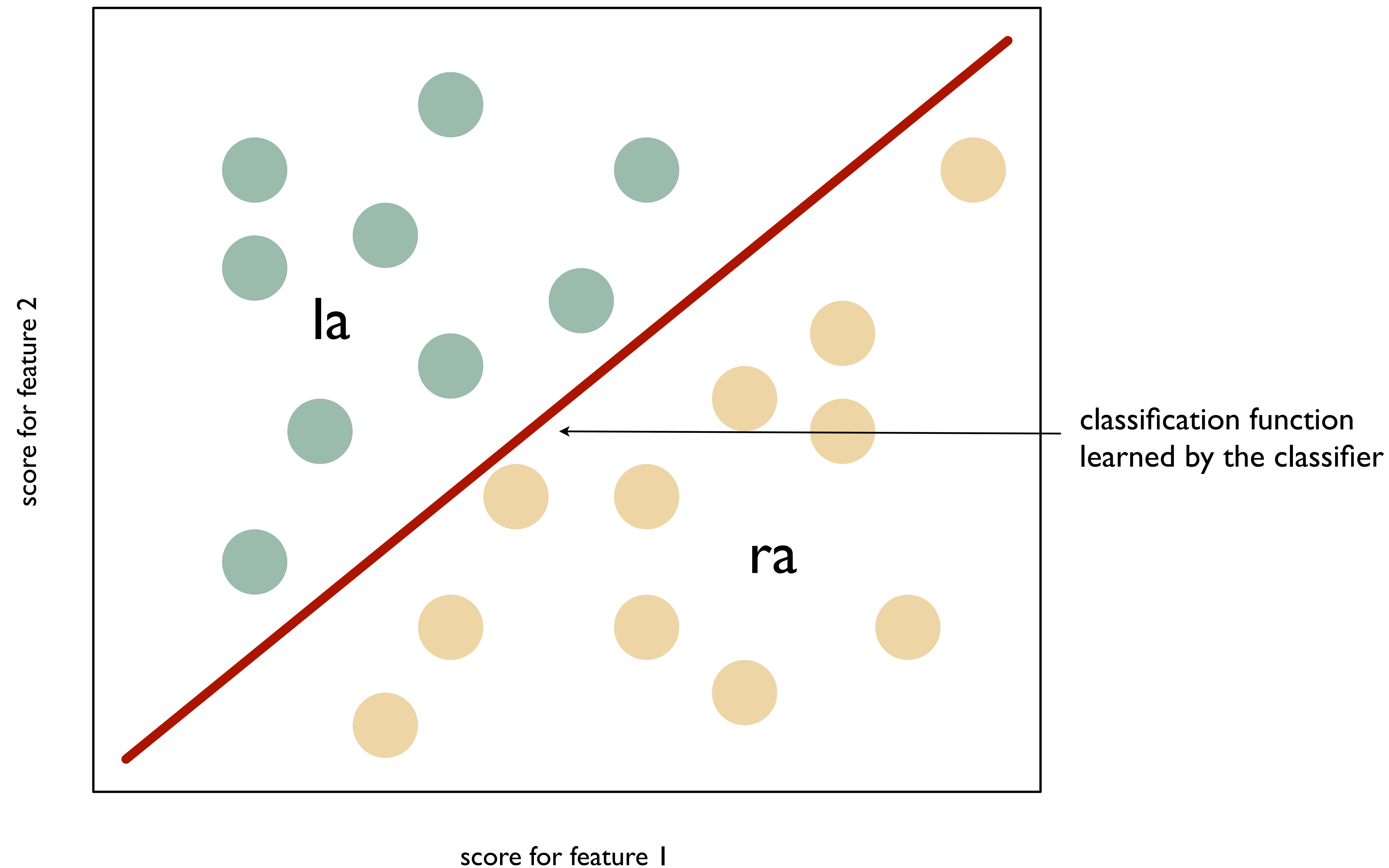
  Example: word forms of the topmost two words on the stack and the next two words in the buffer

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

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, ...

Alternative transition models

Alternatives

- The arc-standard model as I presented it is just one example of a transition model
  - In the book you can see another version of the arc-standard model, where arcs are added between the topmost word on the stack and the tpmost word on the buffer
- There are many other alternatives

Arc-eager model

- Contains four transitions:
  - Shift
  - Reduce
  - Left-arc
  - Right-arc
- Advantage: not strictly bottom-up, can create arcs earlier than in the arc-standard model

Non-projective transition model

- Allows non-projective parsing by adding a swap transition
- Contains four transitions:
  - Shift
  - Swap
  - Left-arc
  - Right-arc
- Runtime is $O(n^2)$ in the worst case (but usually less in practice)

Transition models in Maltparser

- Nivre family
  - Arcs created between stack and buffer
    - arc-eager model
    - arc-standard (variant from course book)
- Stack family
  - Arcs between two topmost words on stack
    - arc-standard model (from slides)
    - models with swap transition
- Other families available as well

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Evaluation of dependency parsing

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Evaluation of dependency parsers

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

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Word- vs sentence-level AS

- 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

- Word-level evalution is normally used

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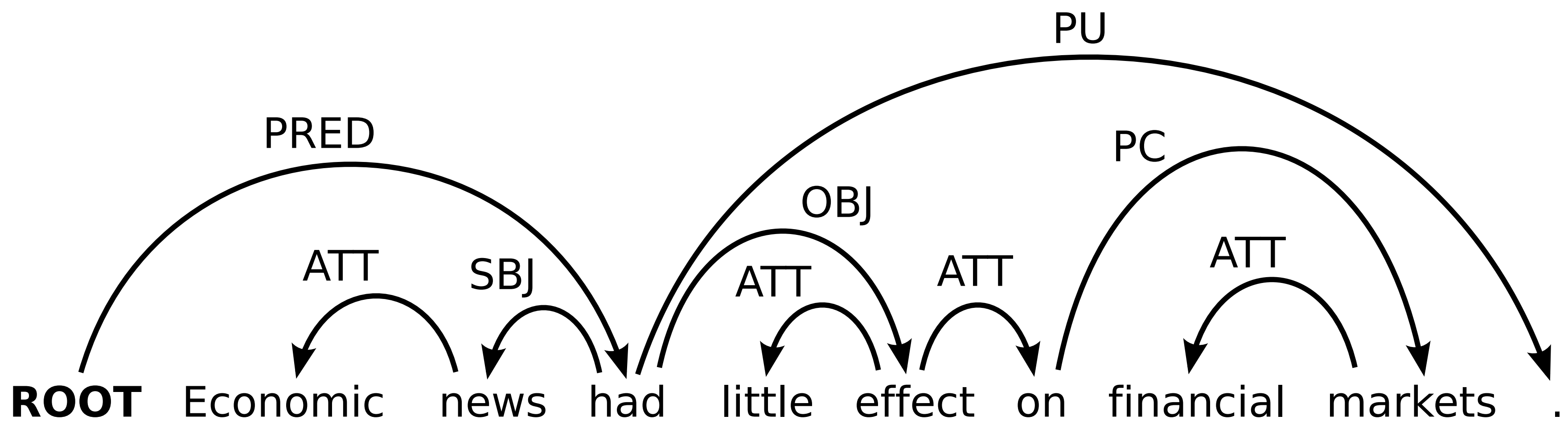
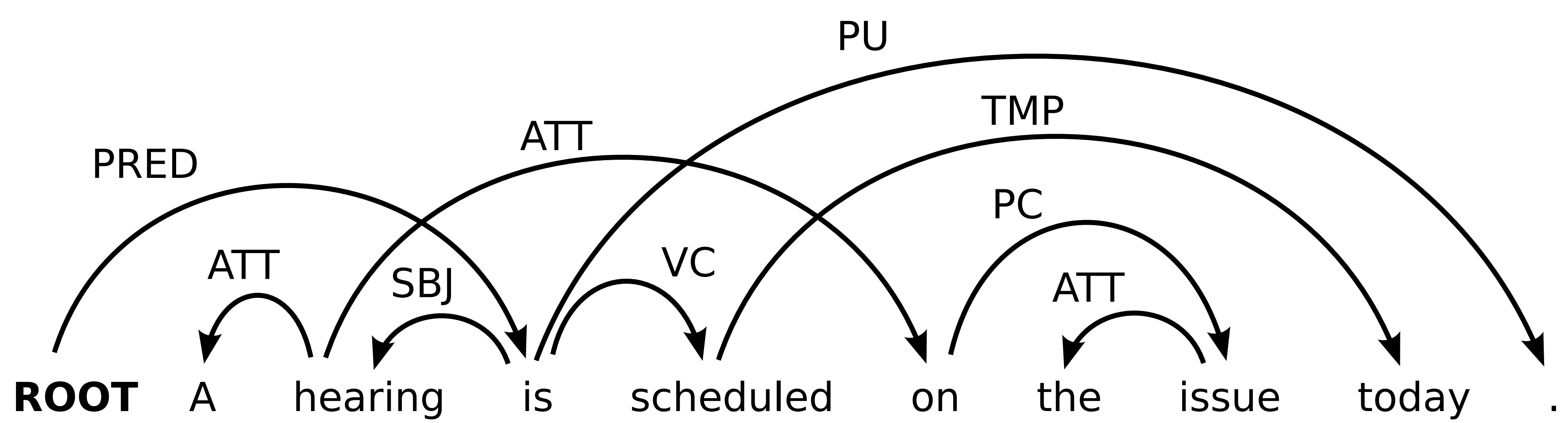
Projectivity

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





Projectivity and dependency parsing

- Many dependency parsing algorithms can only handle projective trees
  - Including all algorithms we have discussed in detail
- 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
  - Using more than one stack
  - Pseudo-projective parsing (seminar 2)
- 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.

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The end of the course

- Seminar 2, Pseudo-projective parsing
  - Easier and shorter article than last seminar, some more general questions
- Assignment 3: Disambiguation in arc-factored and transition-based parsing
- Assignment 4: Try and evaluate MaltParser
- Course evaluation in the student portal