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Collins’ and Eisner’s algorithms

Syntactic analysis (5LN455)

2016-12-06

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Based on slides from Marco Kuhlmann

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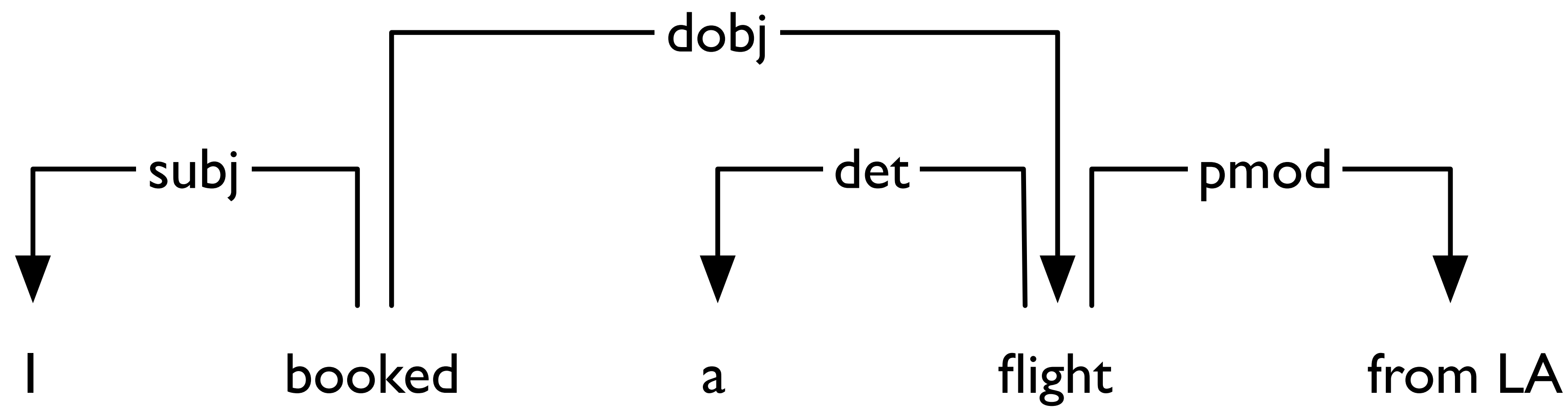
Recap: Dependency trees



- In an arc $h \rightarrow d$, the word *h* is called the head, and the word *d* is called the dependent.
- The arcs form a rooted tree.

Recap: Scoring models and parsing algorithms

Distinguish two aspects:

- Scoring model:
  How do we want to score dependency trees?
- Parsing algorithm:
  How do we compute a highest-scoring dependency tree under the given scoring model?

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Recap: The arc-factored model

- To score a dependency tree, score the individual arcs, and combine the score into a simple sum.

  $\text{score}(t) = \text{score}(a_1) + \ldots + \text{score}(a_n)$

- Define the score of an arc $h \rightarrow d$ as the weighted sum of all features of that arc:

  $\text{score}(h \rightarrow d) = f_1 w_1 + \ldots + f_n w_n$

Recap: Example features

- ‘The head is a verb.’
- ‘The dependent is a noun.’
- ‘The head is a verb
  and the dependent is a noun.’
- ‘The head is a verb
  and the predecessor of the head is a pronoun.’
- ‘The arc goes from left to right.’
- ‘The arc has length 2.’

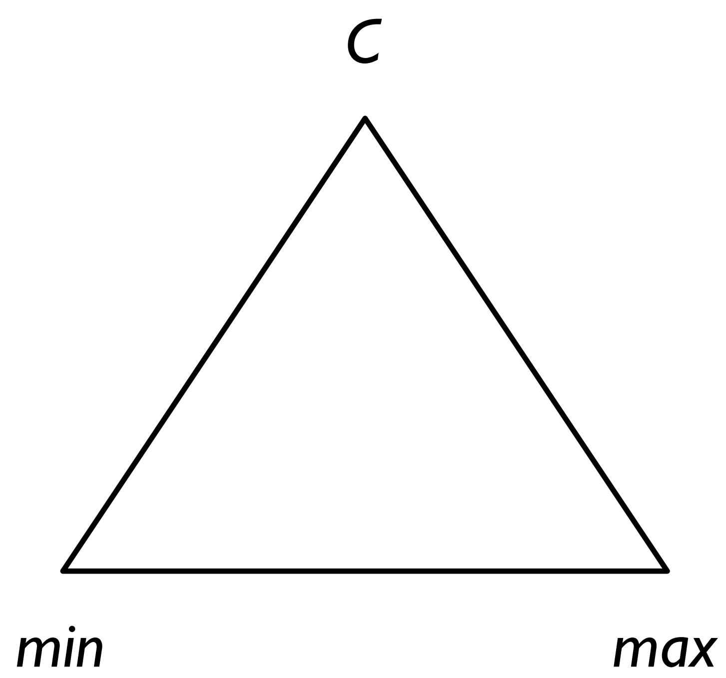
Recap: Training using structured prediction

- Take a sentence *w* and a gold-standard dependency tree *g* for *w*.
- Compute the highest-scoring dependency tree under the current weights; call it *p*.
- Increase the weights of all features that are in *g* but not in *p*.
- Decrease the weights of all features that are in *p* but not in *g*.

Recap: Collin’s algorithm

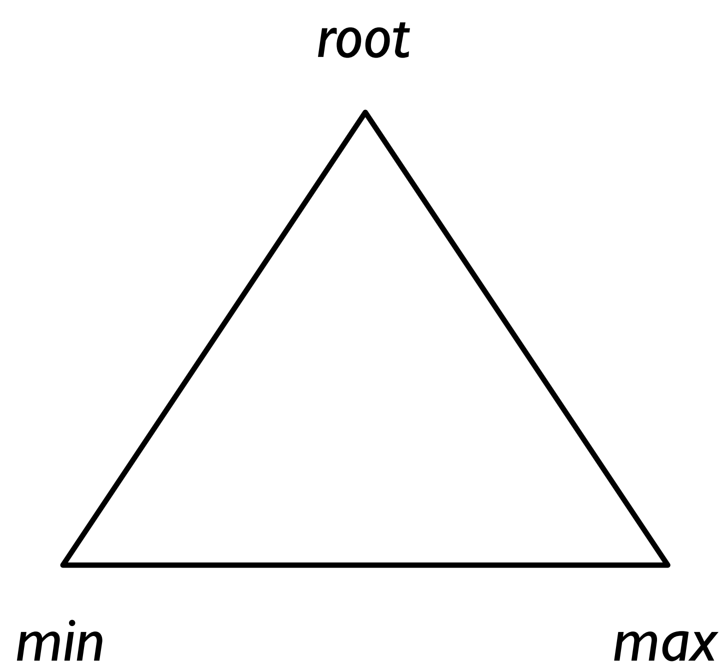
- Collin’s algorithm is a simple algorithm for computing the highest-scoring dependency tree under an arc-factored scoring model.
- It can be understood as an extension of the CKY algorithm to dependency parsing.
- Like the CKY algorithm, it can be characterized as a bottom-up algorithm based on dynamic programming.

Recap: Signatures



[*min*, *max*, *C*]

Recap: Signatures



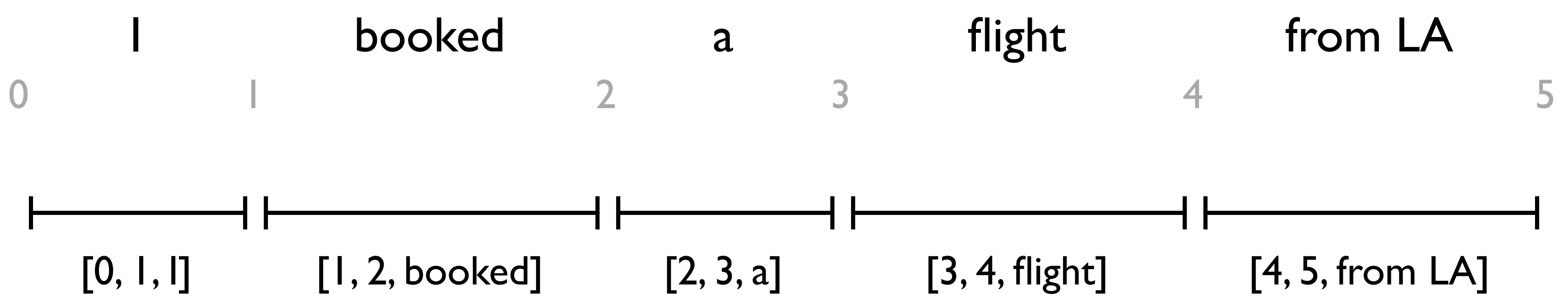
[*min*, *max*, *root*]

Recap: Initialization

I	booked	a	flight	from LA

0 1 2 3 4 5

Recap: Initialization



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Recap: Adding a left-to-right arc

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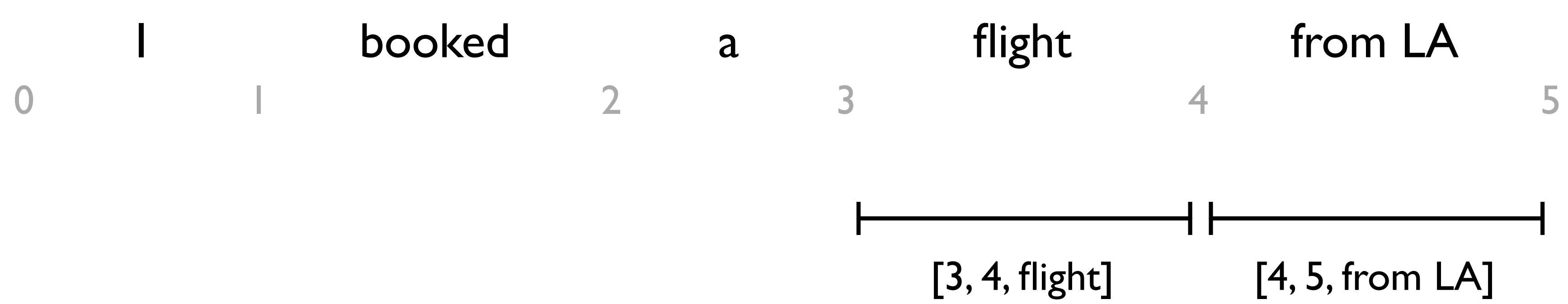
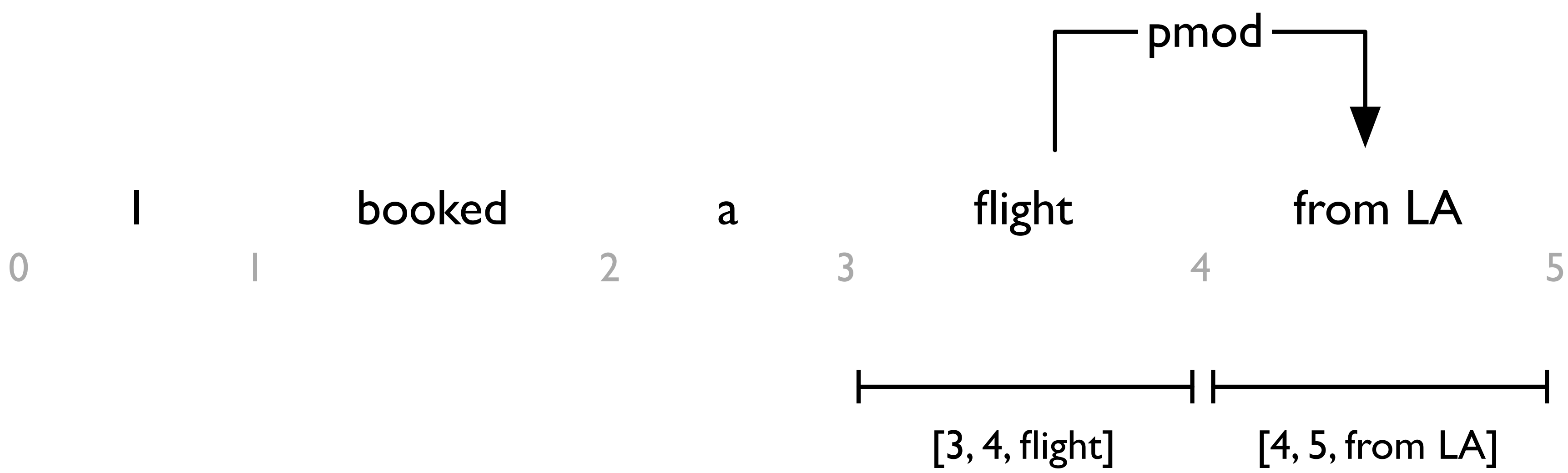
0 1 2 3 4 5

Recap: Adding a left-to-right arc



Recap: Adding a left-to-right arc



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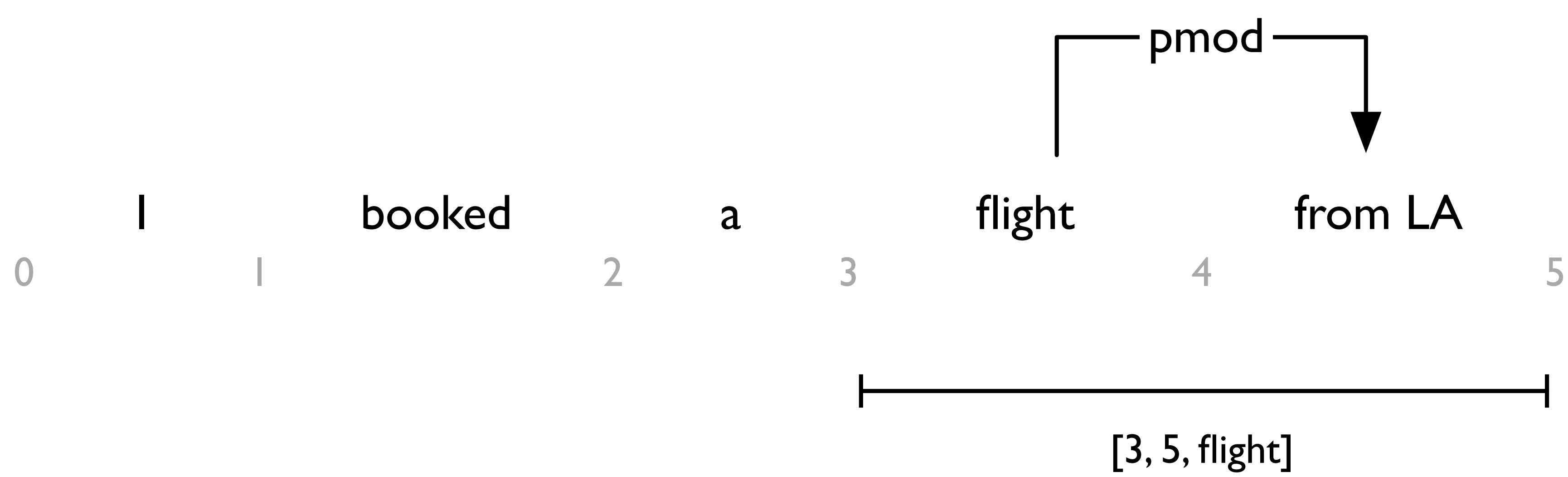

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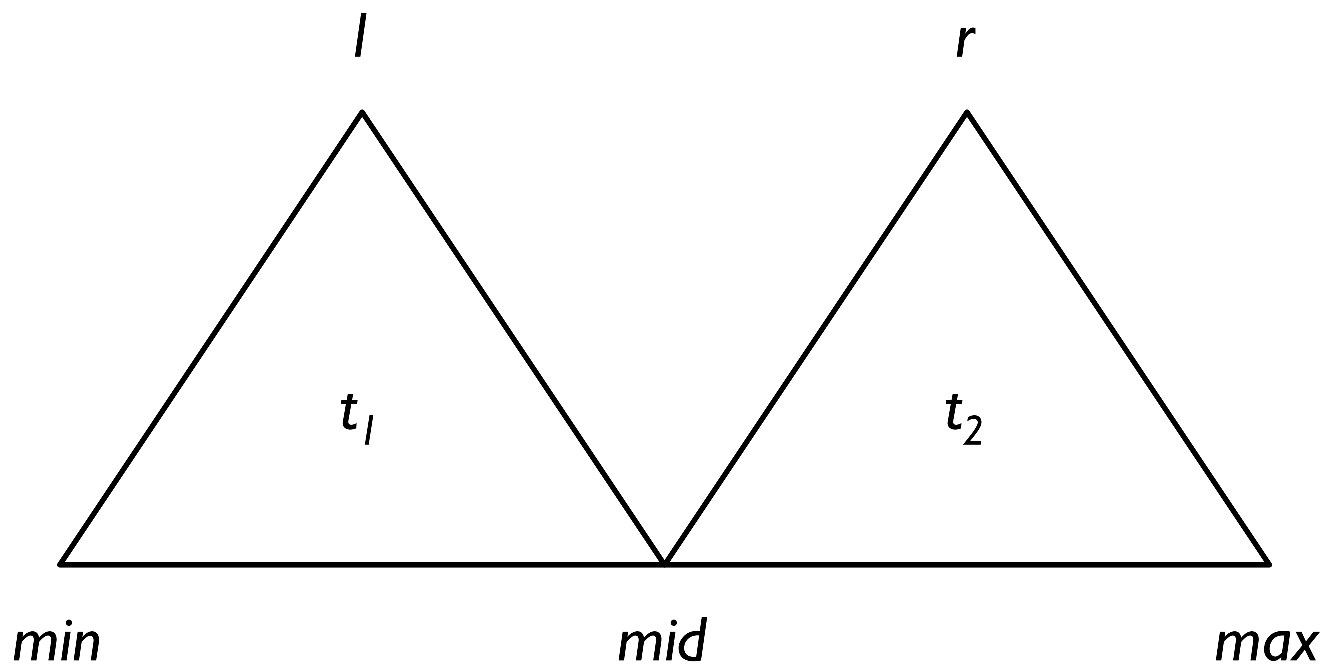

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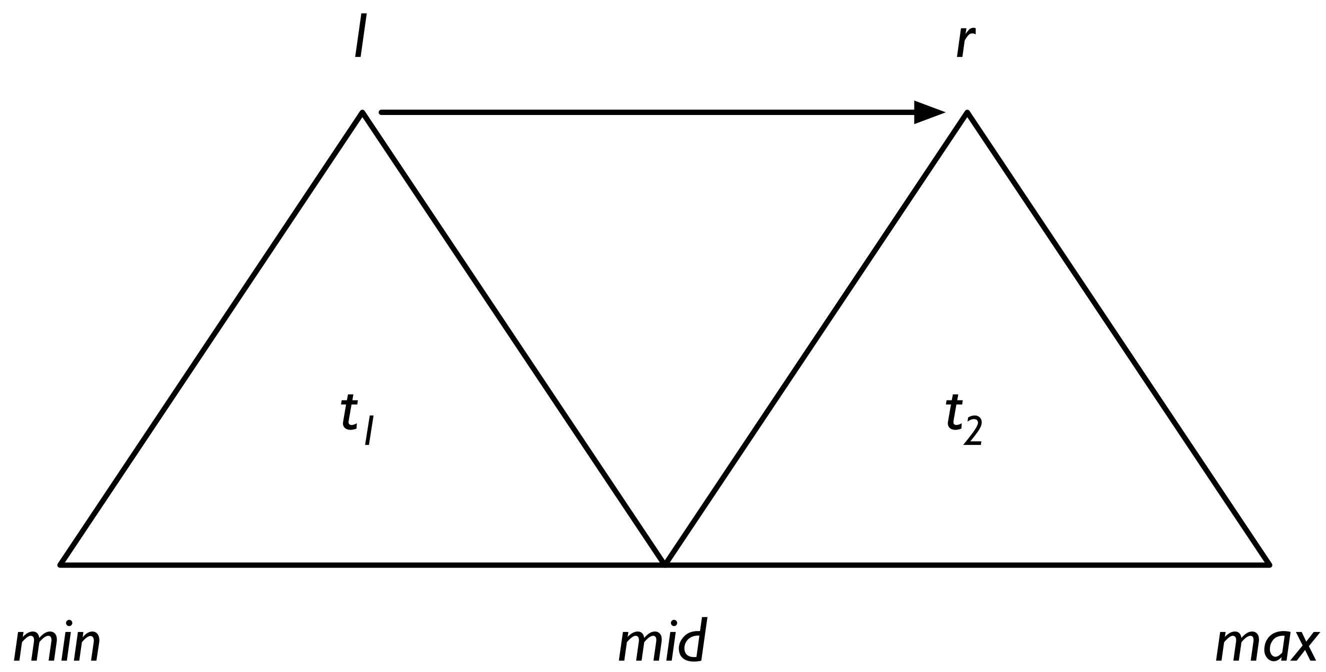
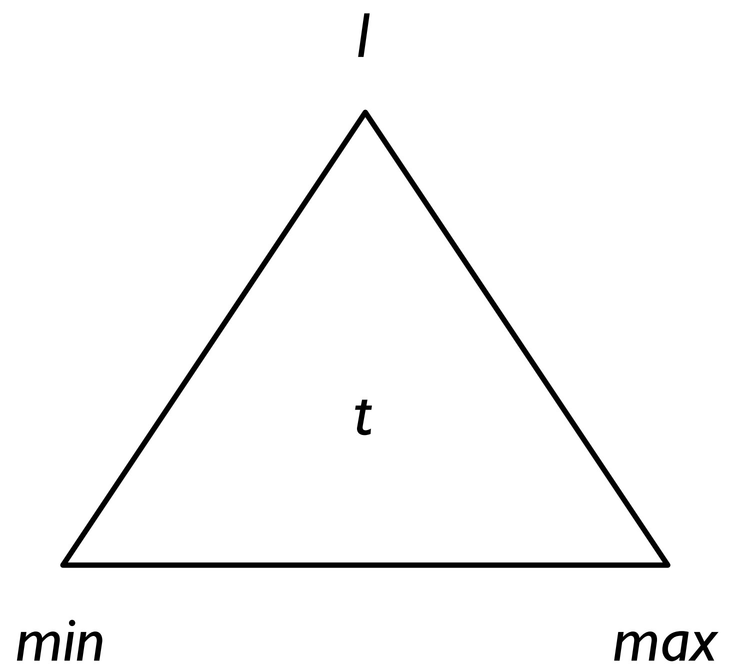
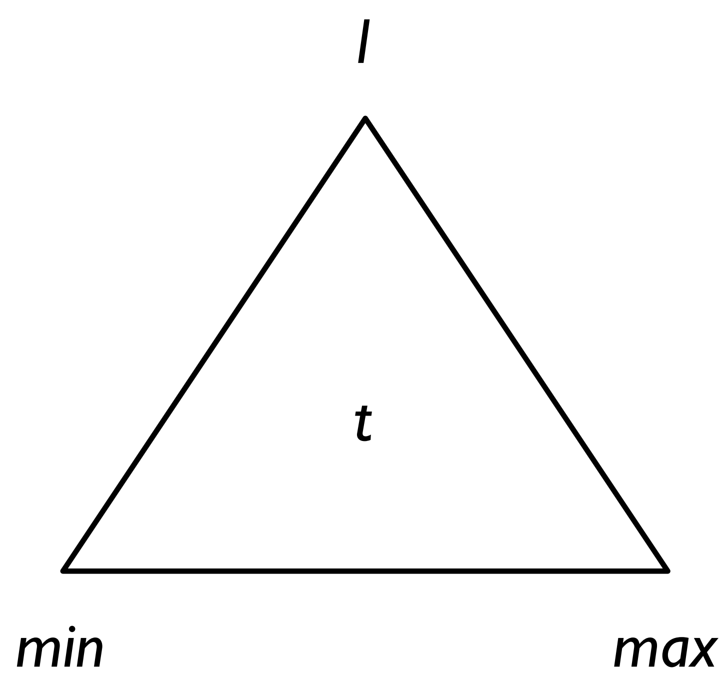


Recap: Adding a left-to-right arc



Recap: Adding a left-to-right arc

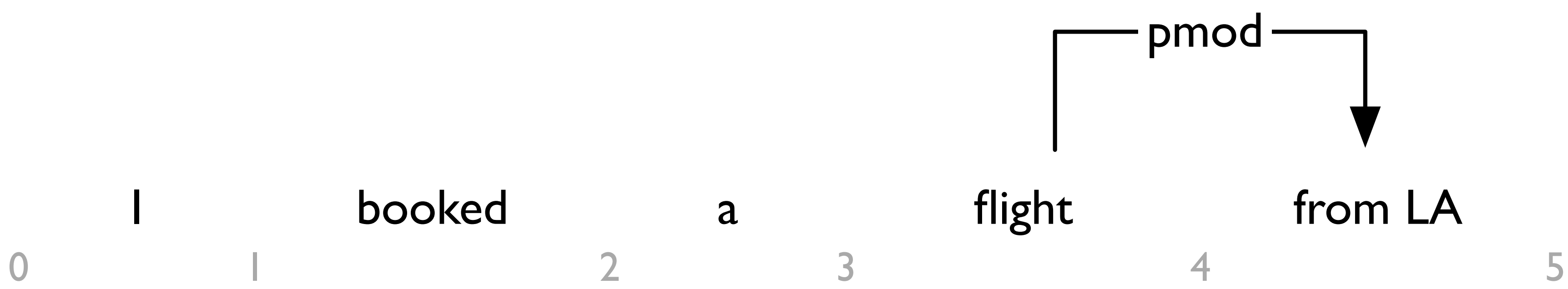


$$\text{score}(t) = \text{score}(t_1) + \text{score}(t_2) + \text{score}(l \rightarrow r)$$

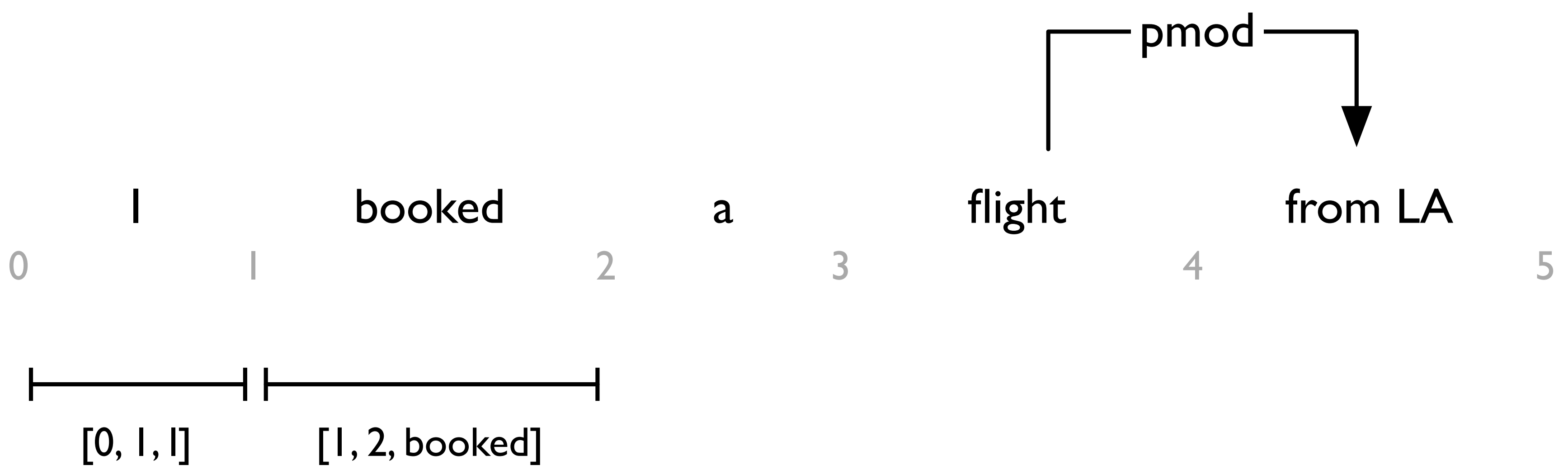
Adding a left-to-right arc

```
for each [min, max] with max - min > 1 do
  for each l from min to max - 2 do
    double best = score[min][max][l]
    for each r from l + 1 to max - 1 do
      for each mid from l + 1 to r do
        t₁ = score[min][mid][l]
        t₂ = score[mid][max][r]
        double current = t₁ + t₂ + score(l → r)
        if current > best then
          best = current
    score[min][max][l] = best
```

Adding a right-to-left arc

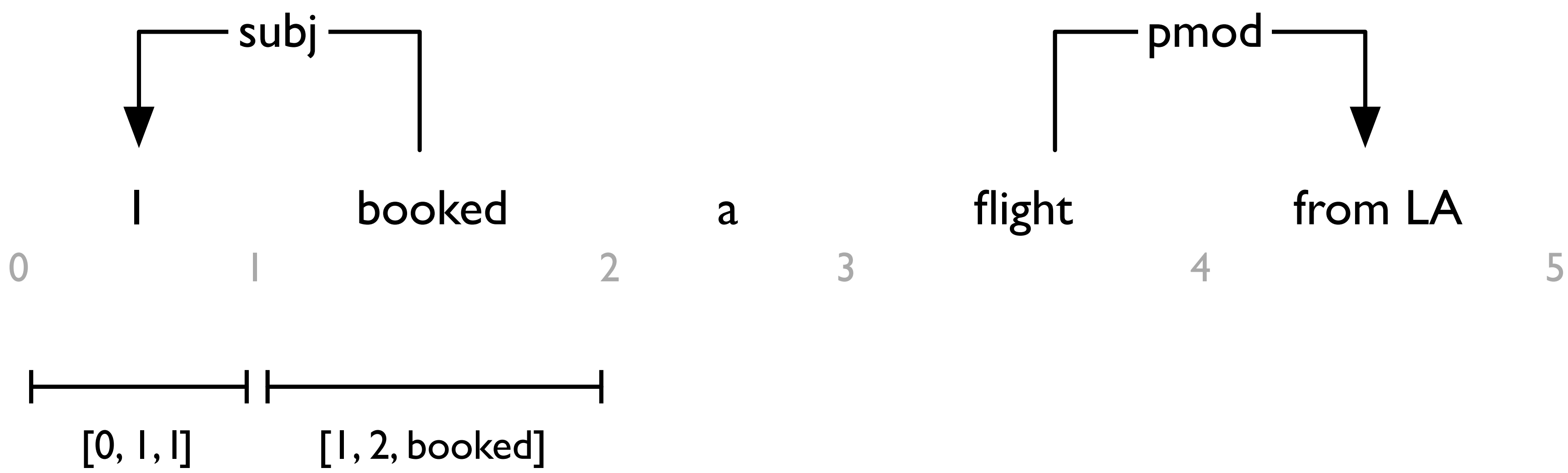


Adding a right-to-left arc

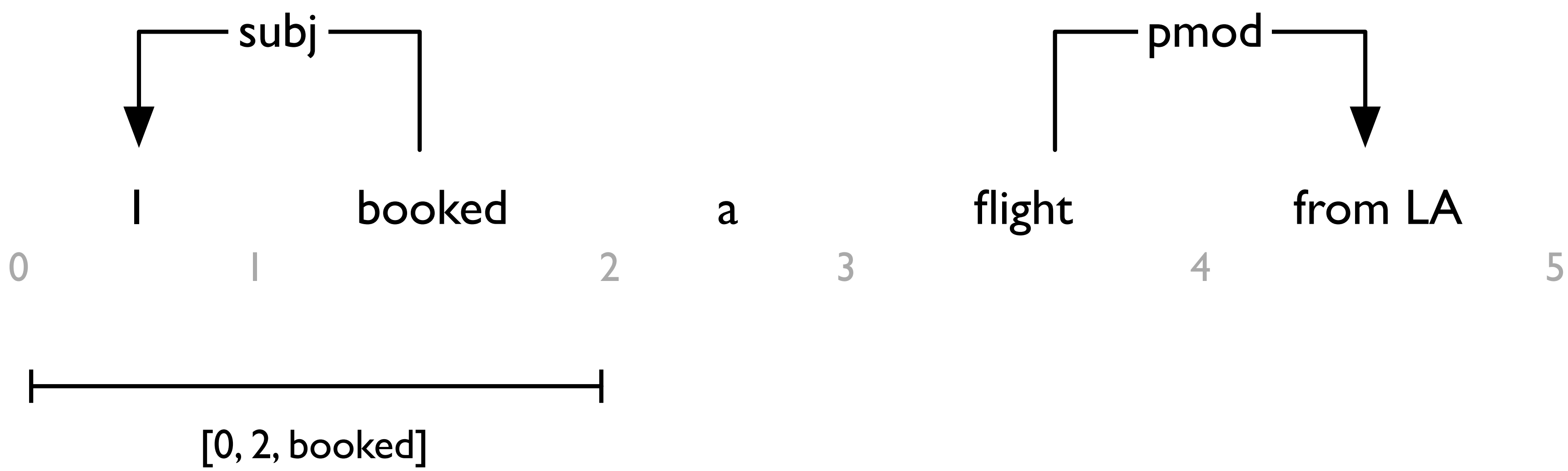


Collins' algorithm

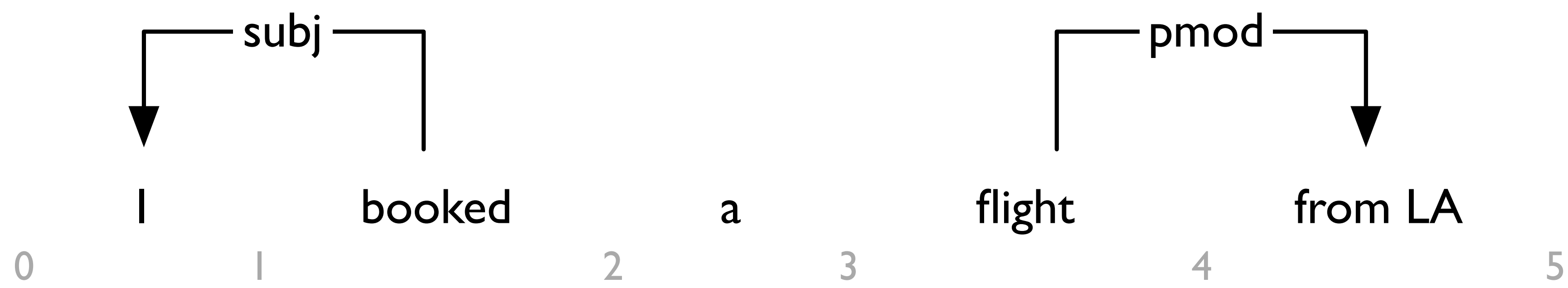
Adding a right-to-left arc



Adding a right-to-left arc



Finishing up



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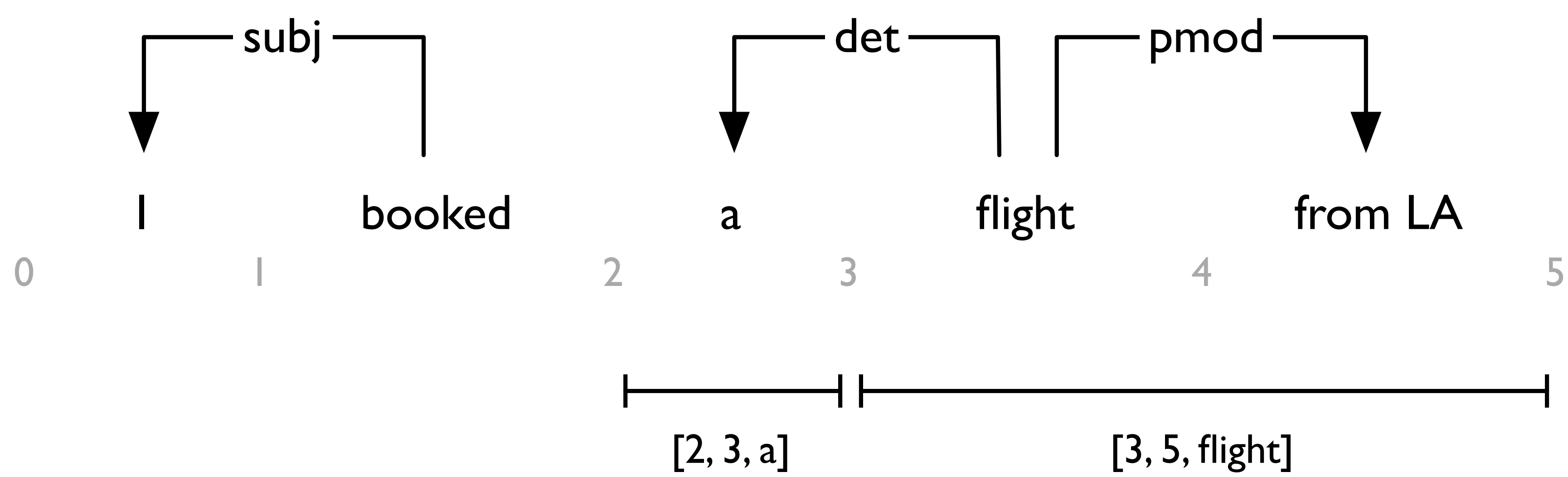

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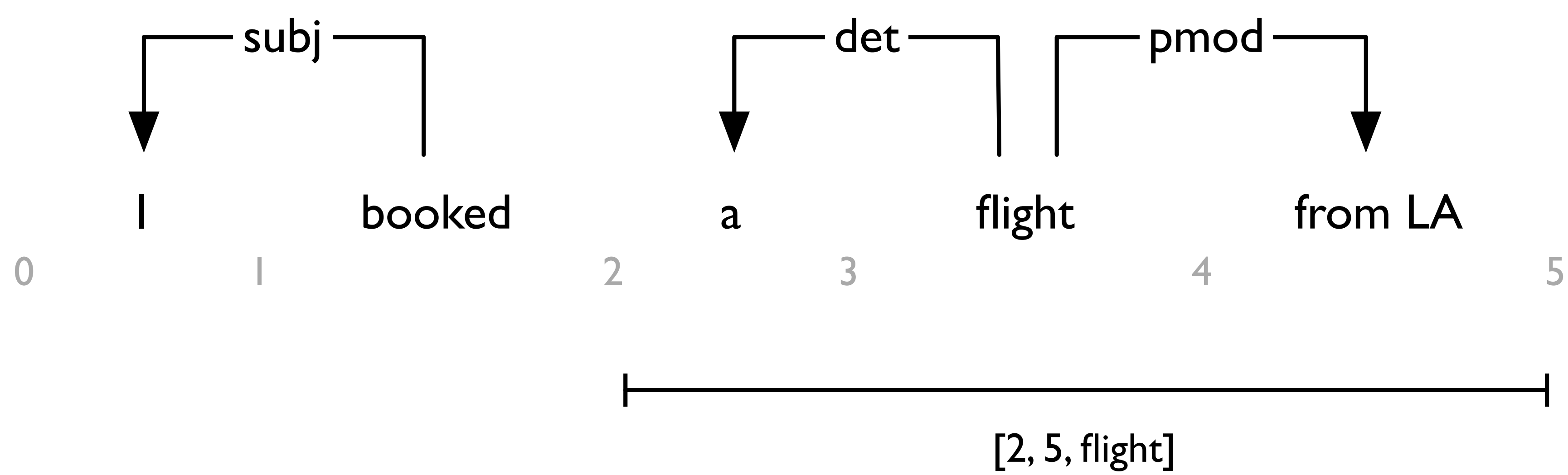

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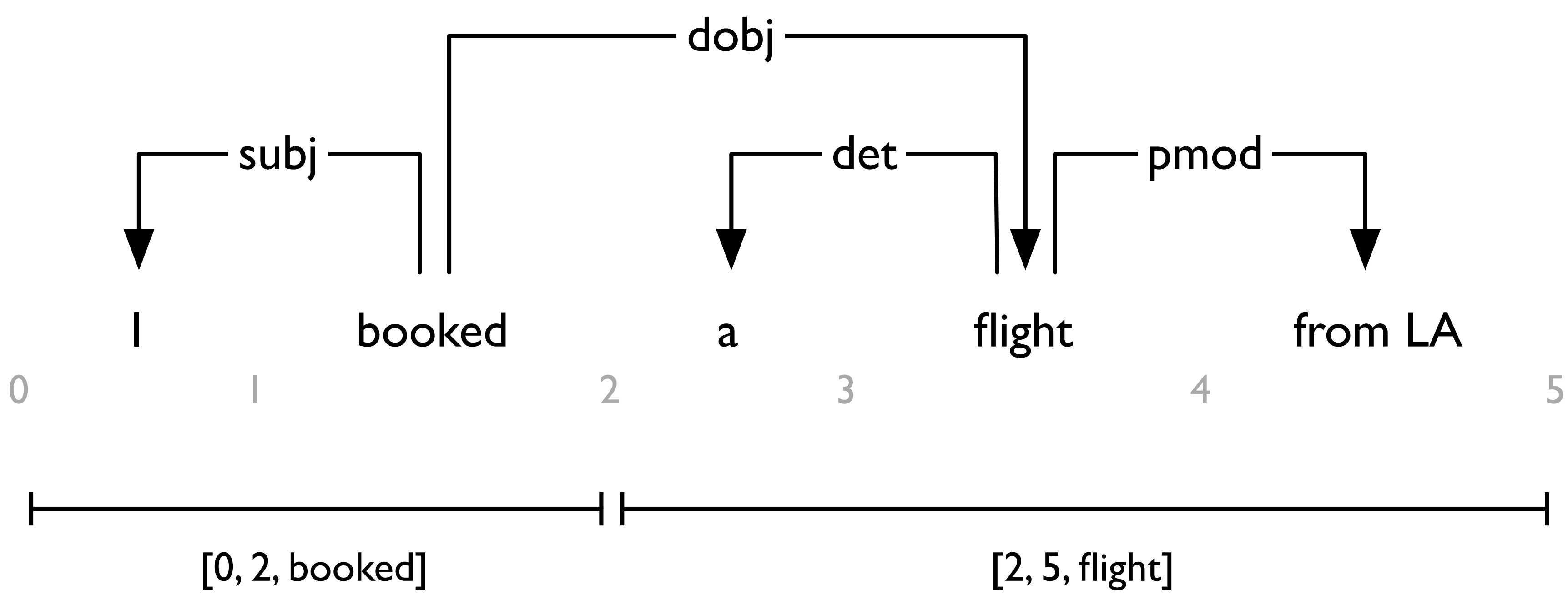

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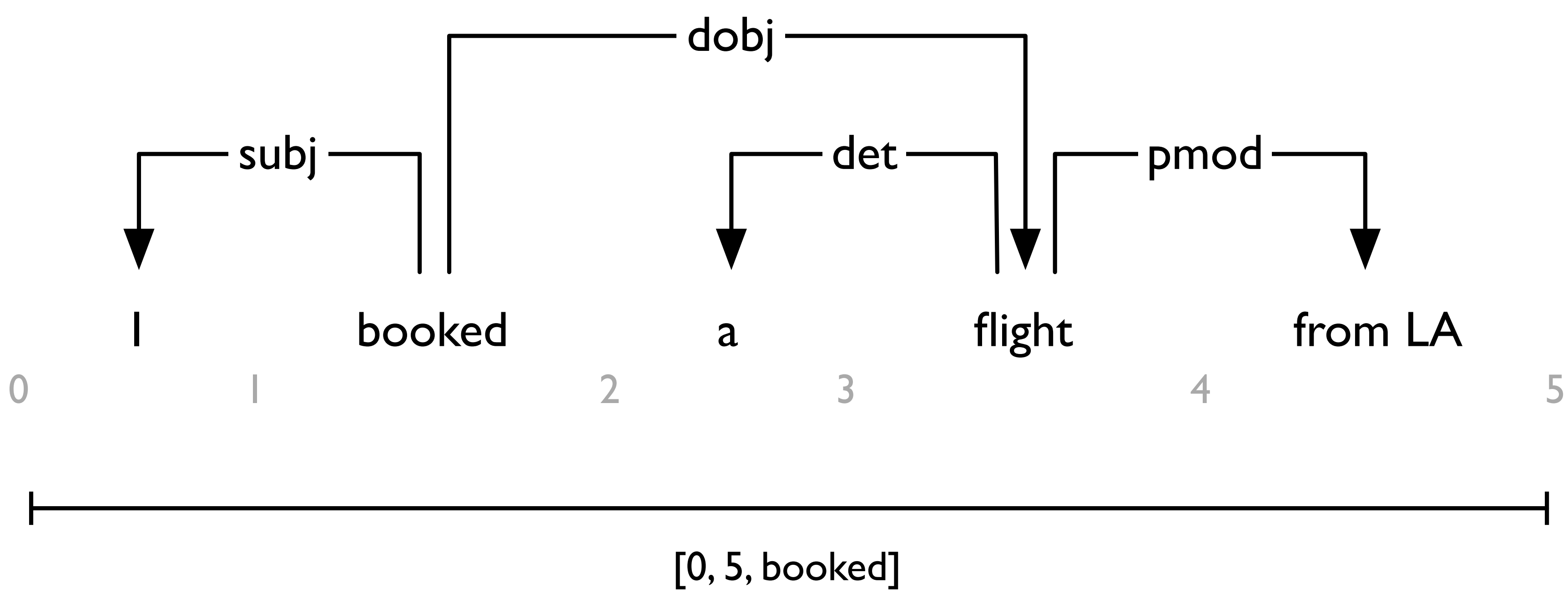

Recap: Complexity analysis

- Space requirement:
  $O(|w|^3)$
- Runtime requirement:
  $O(|w|^5)$

Extension to the labeled case

- It is important to distinguish dependencies of different types between the same two words.

  Example: subj, dobj

- For this reason, practical systems typically deal with labeled arcs.
- The question then arises how to extend Collins' algorithm to the labeled case.

Naive approach

- Add an innermost loop that iterates over all edge labels in order to find the combination that maximizes the overall score.
- For each step of the original algorithm, we now need to make $|L|$ steps, where L is the set of all labels.

Smart approach

- Before parsing, compute a table that lists, for each head–dependent pair (h, d), the label that maximizes the score of arcs $h \rightarrow d$.
- During parsing, simply look up the best label in the precomputed table.
- This adds (not multiplies!) a factor of $|L||w|^2$ to the overall runtime of the algorithm.

Summary

- Collins’ algorithm is a CKY-style algorithm for computing the highest-scoring dependency tree under an arc-factored scoring model.
- It runs in time $O(|w|^5)$.
  This may not be practical for long sentences.

Eisner’s algorithm

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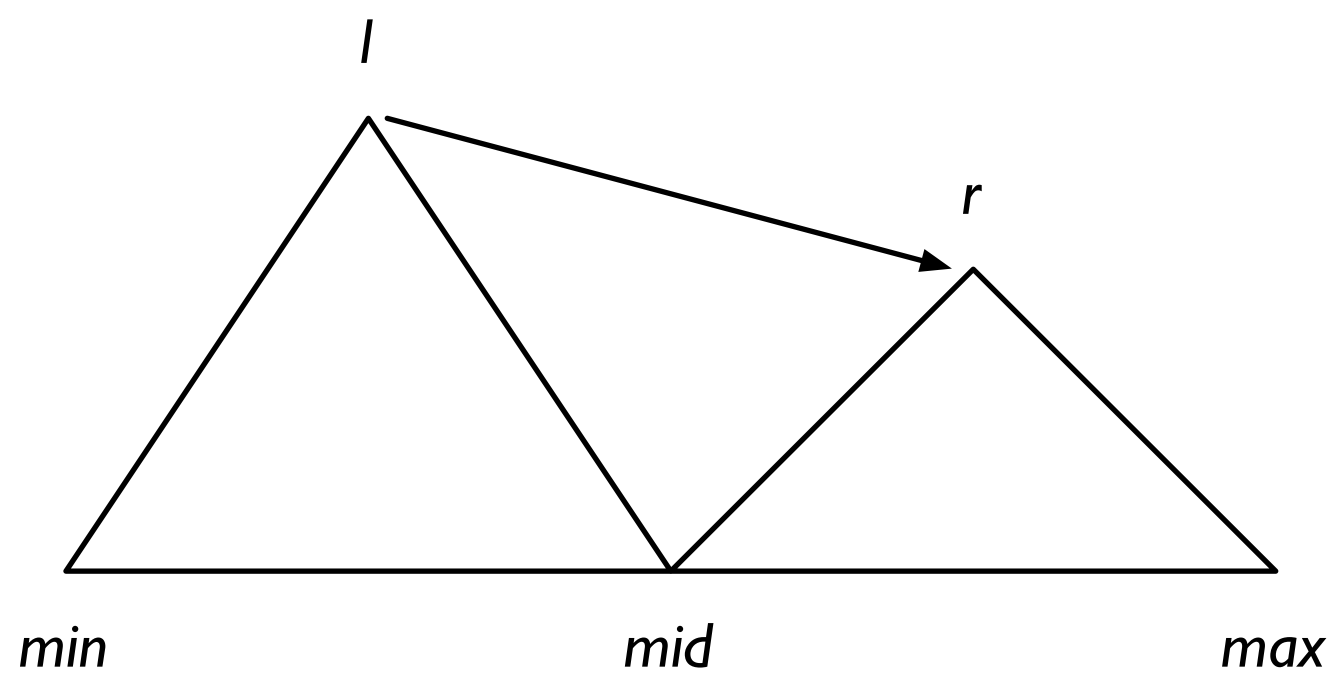
Eisner's algorithm

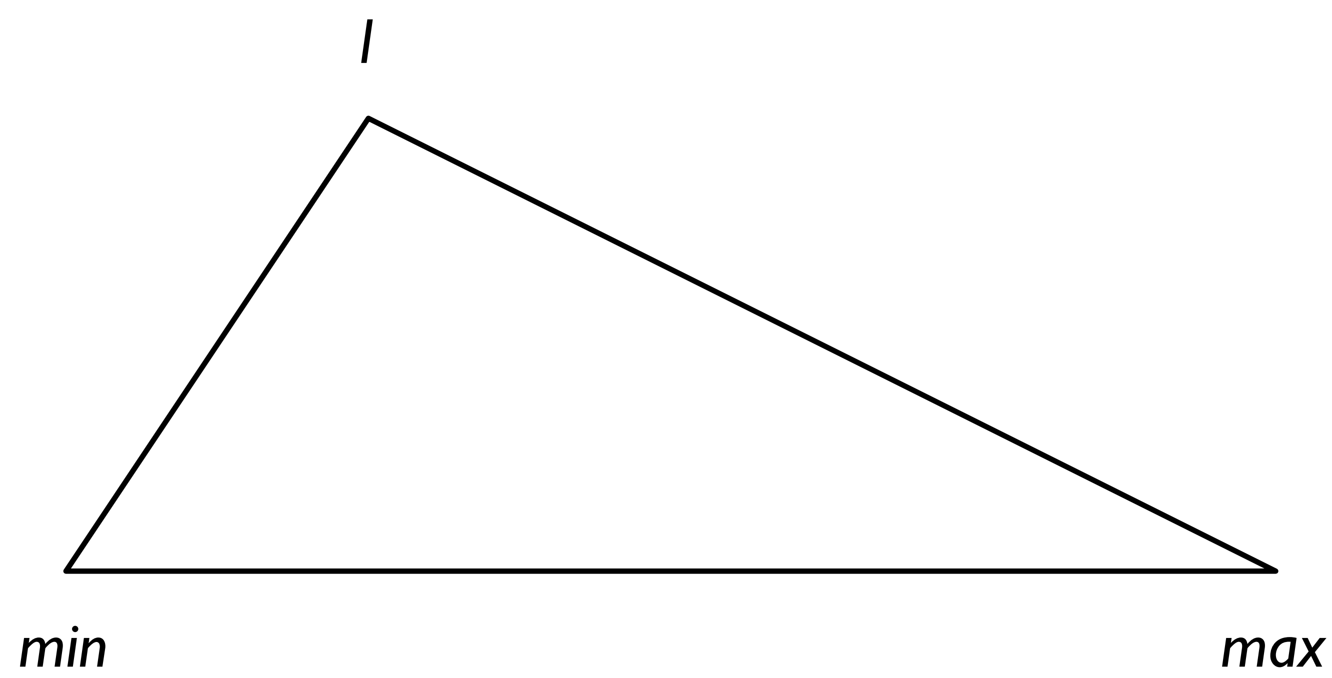
- With its runtime of $O(|w|^5)$, Collins' algorithm may not be of much use in practice.
- With Eisner's algorithm we will be able to solve the same problem in $O(|w|^3)$.
    - Intuition: collect left and right dependents independently

Basic idea



In Collins' algorithm, adding a left-to-right arc is done in one single step, specified by 5 positions.

Basic idea



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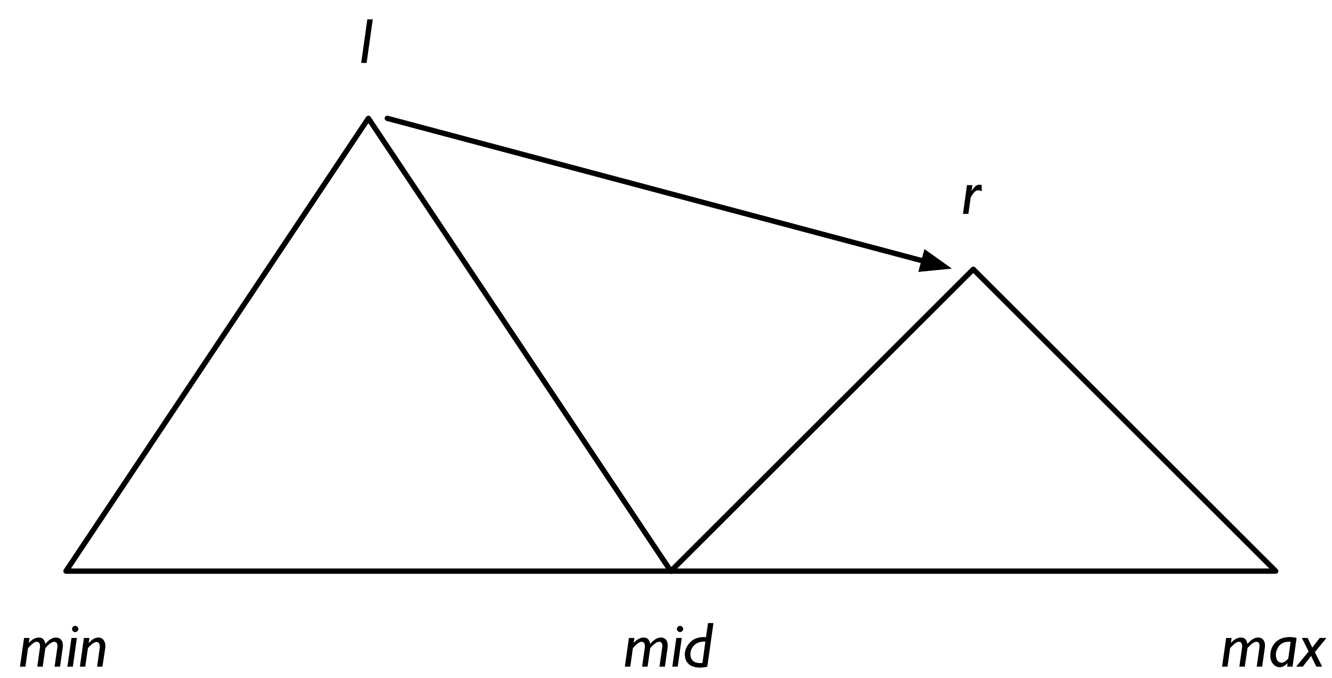
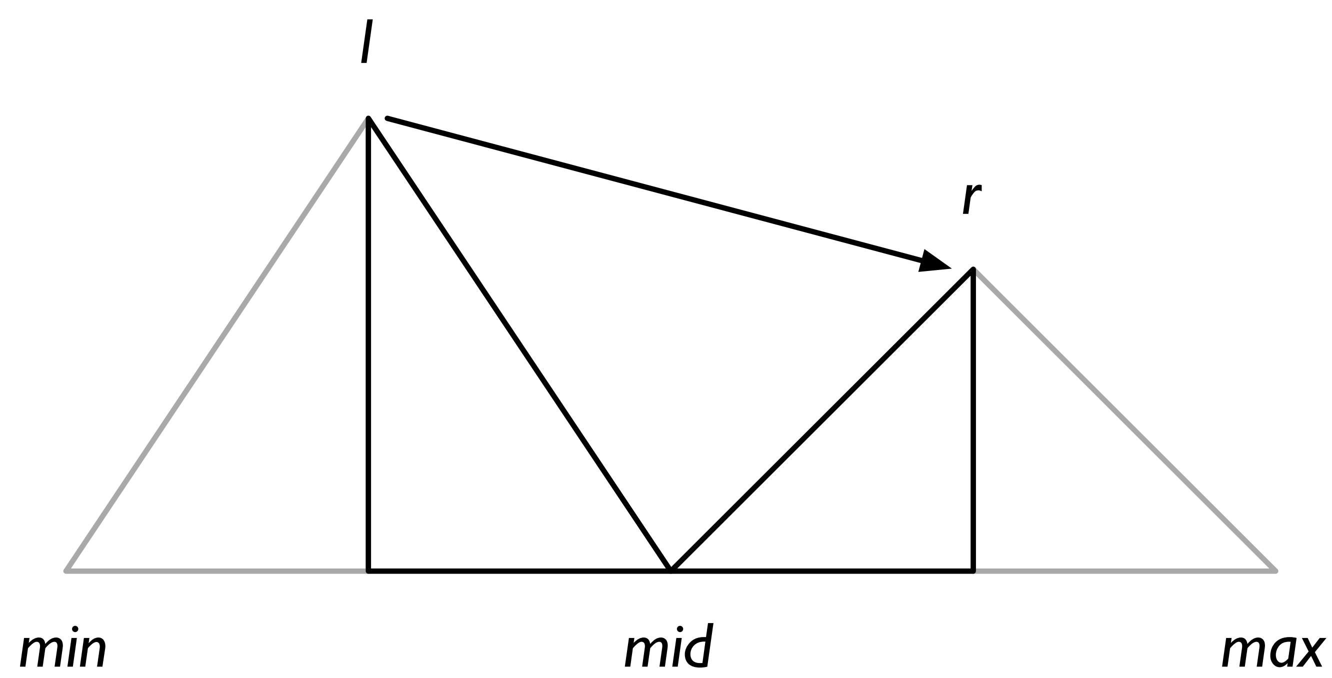


In Eisner’s algorithm, the same thing is done in three steps, each one specified by 3 positions.

Basic idea



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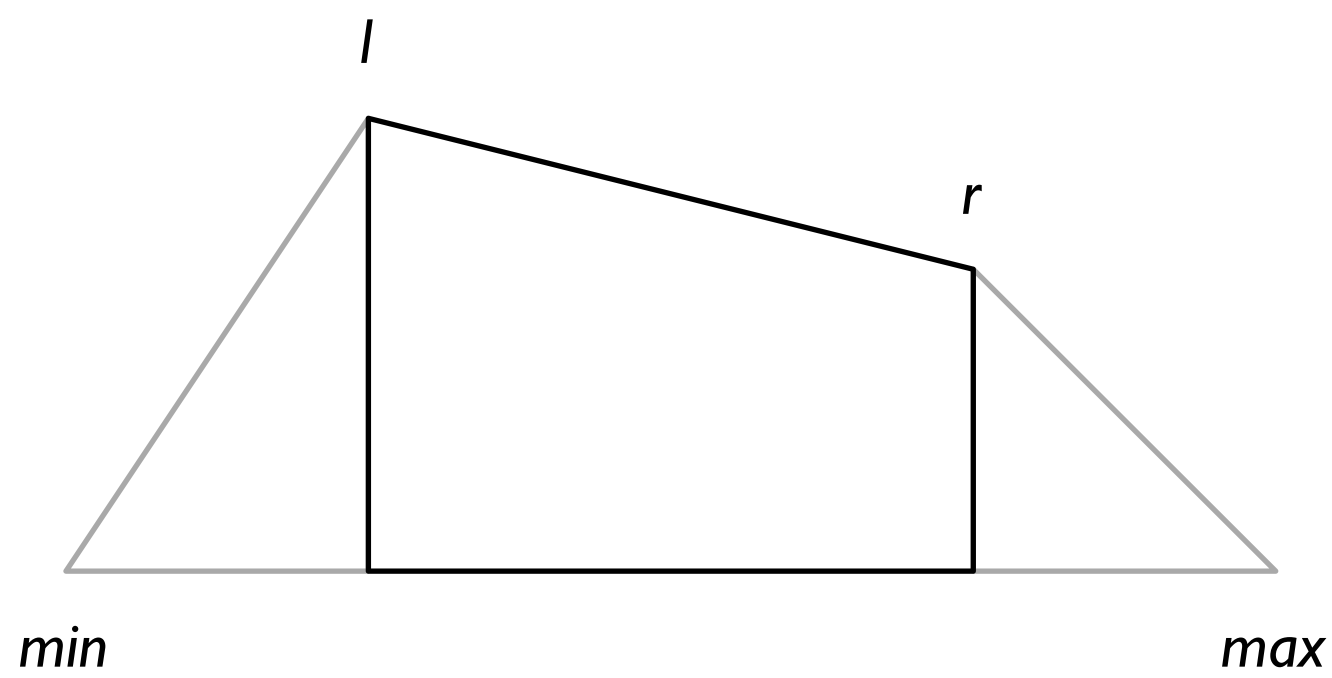

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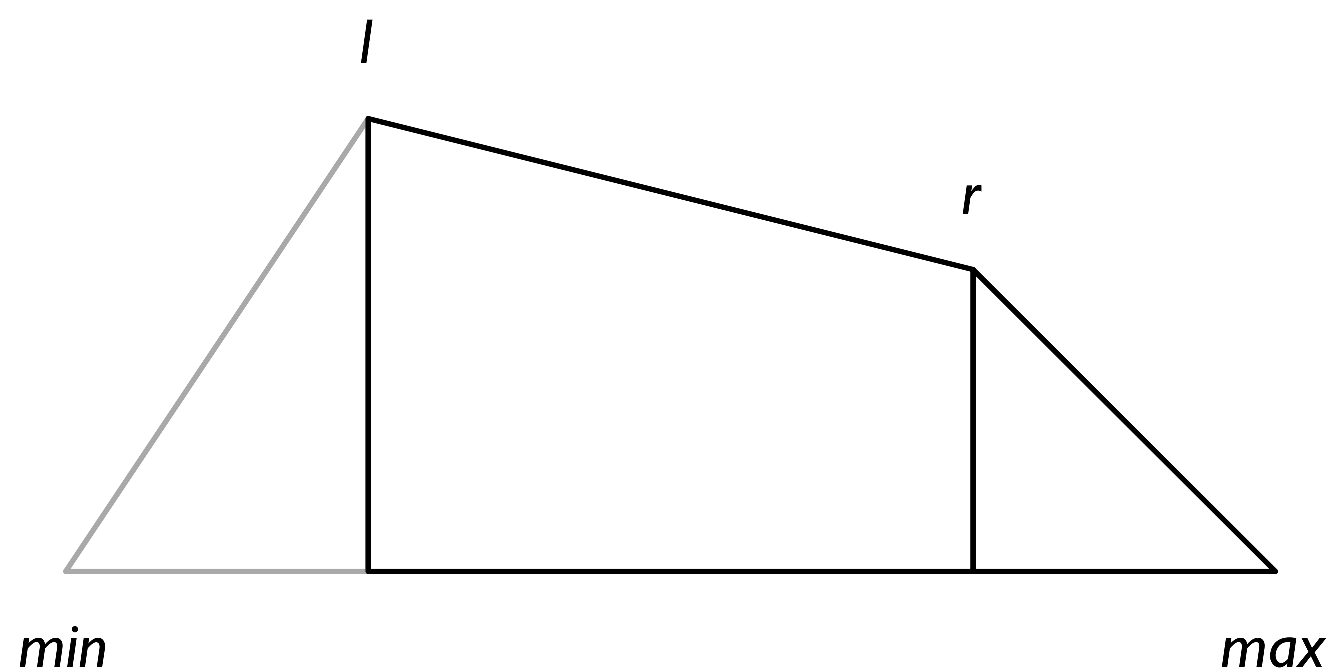

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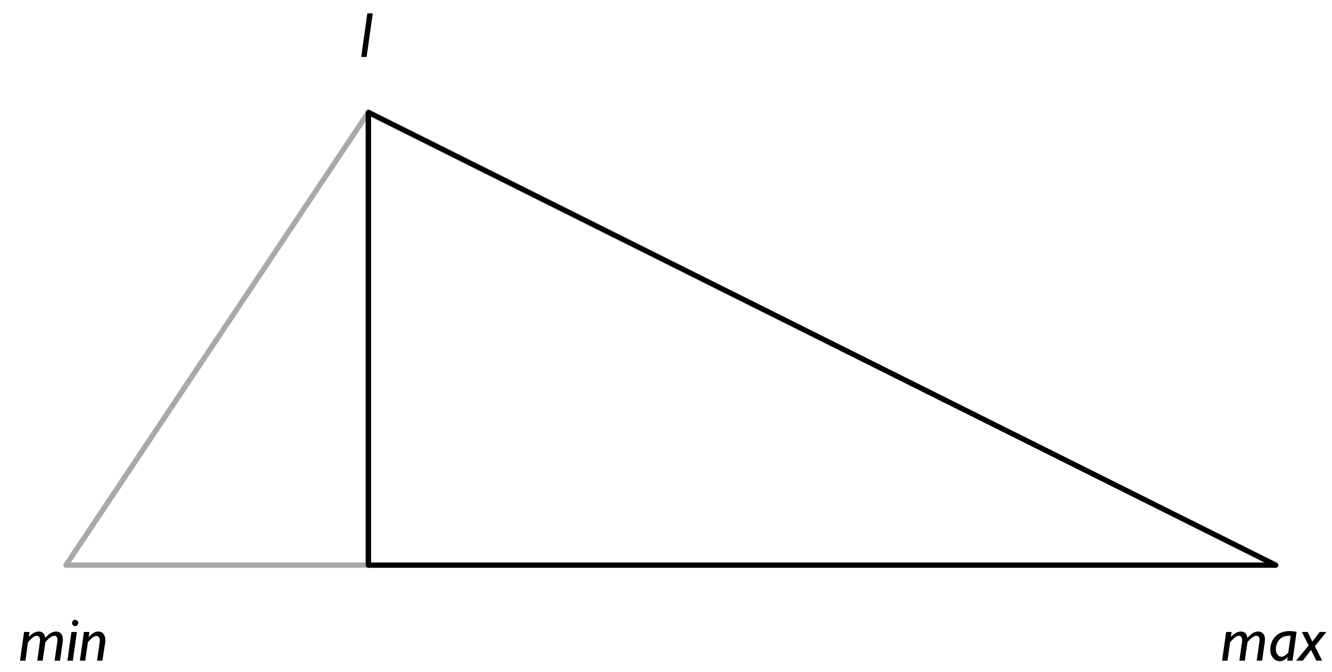

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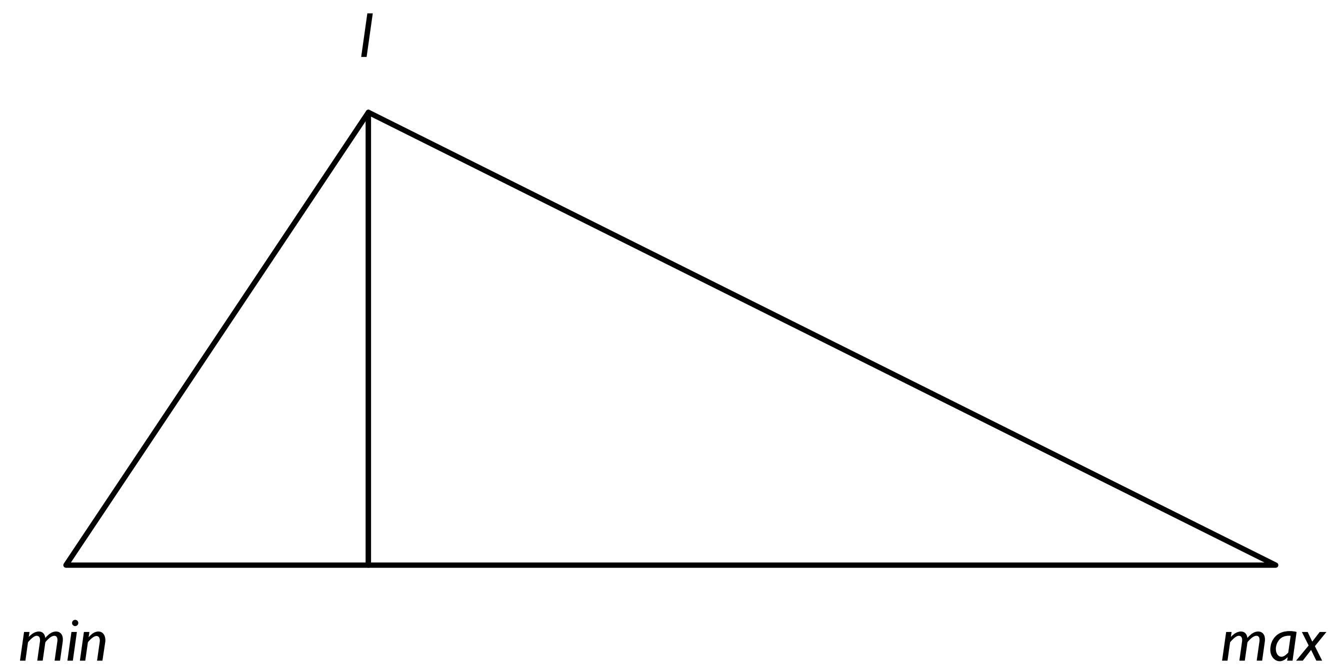

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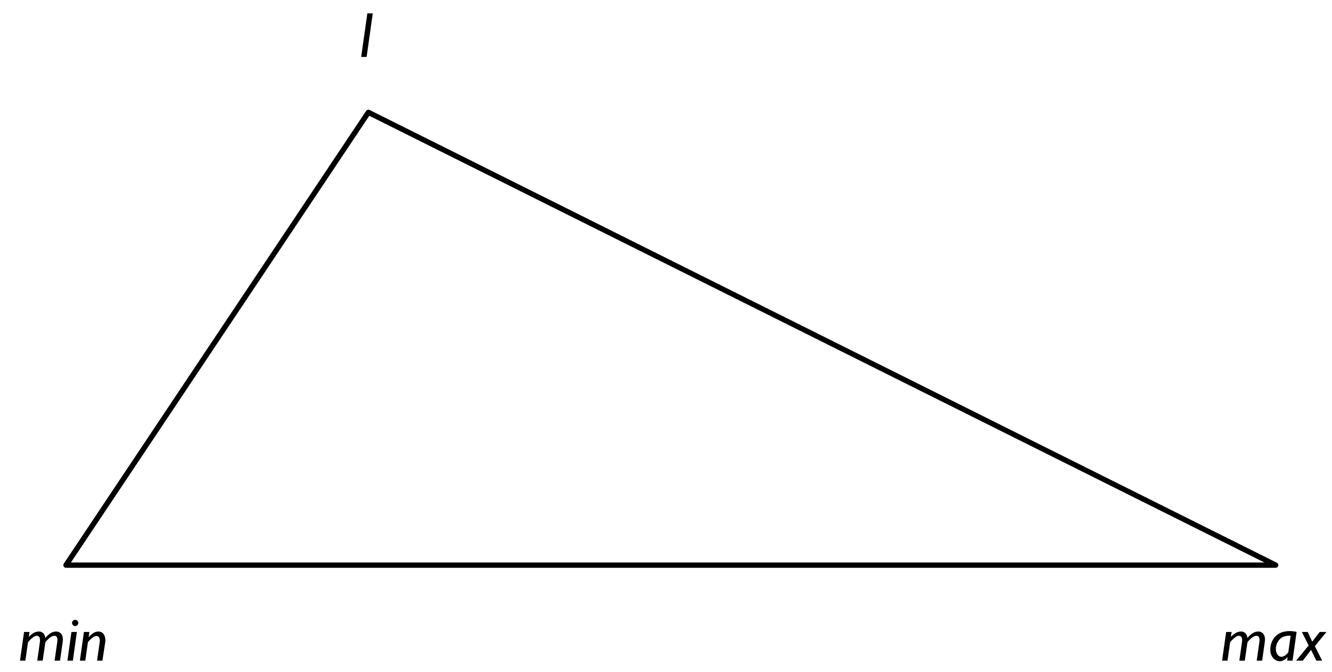

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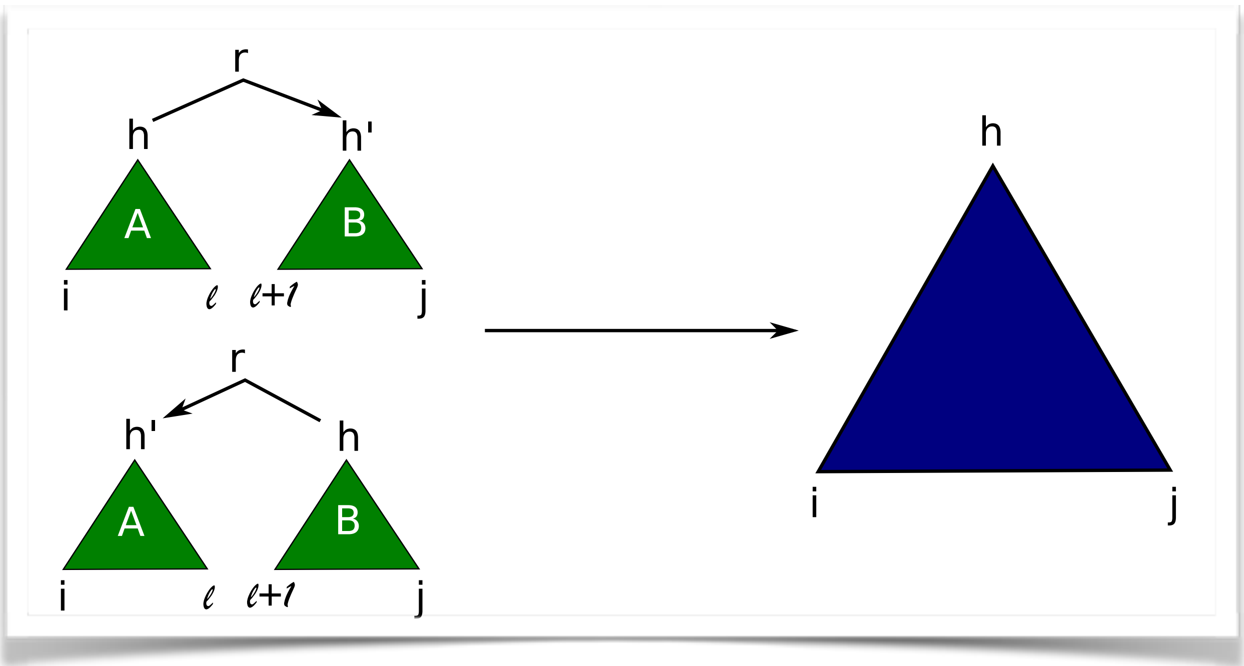
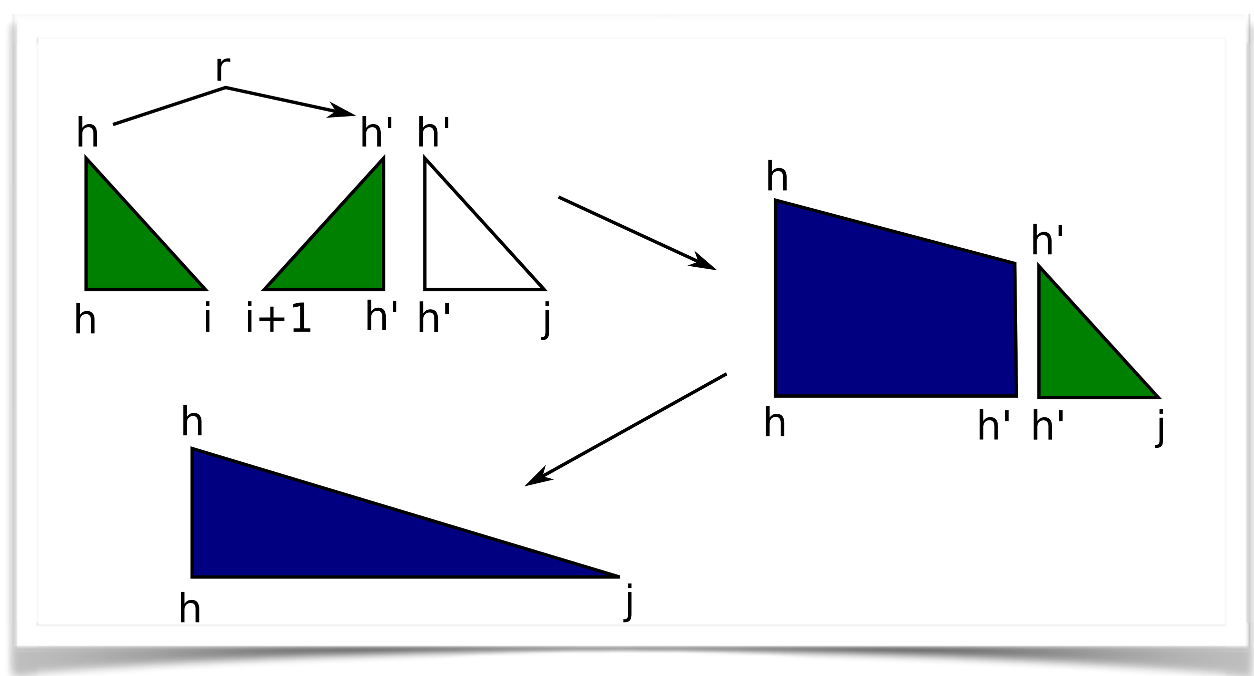
Eisner's algorithm

Comparison



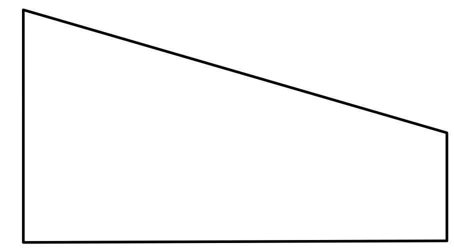


Dynamic programming tables

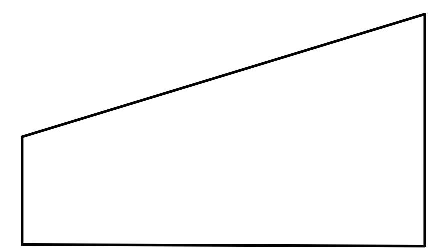
- Collins':
  - [min,max,head]
- Eisner's
  - [min,max,head-side,complete]
    - head-side (binary): is head to the left or right?
    - complete (binary:) is the non-head side still looking for dependents?

Graphic representation

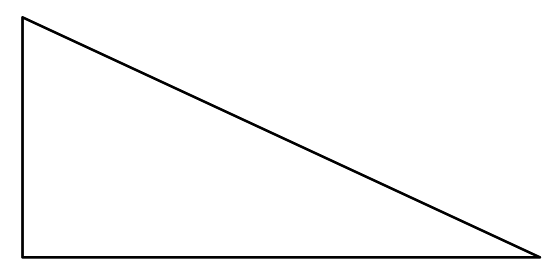
- [min,max,left,yes]



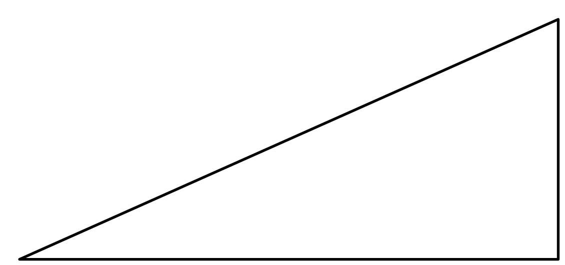
- [min,max,right,yes]



- [min,max,left,no]

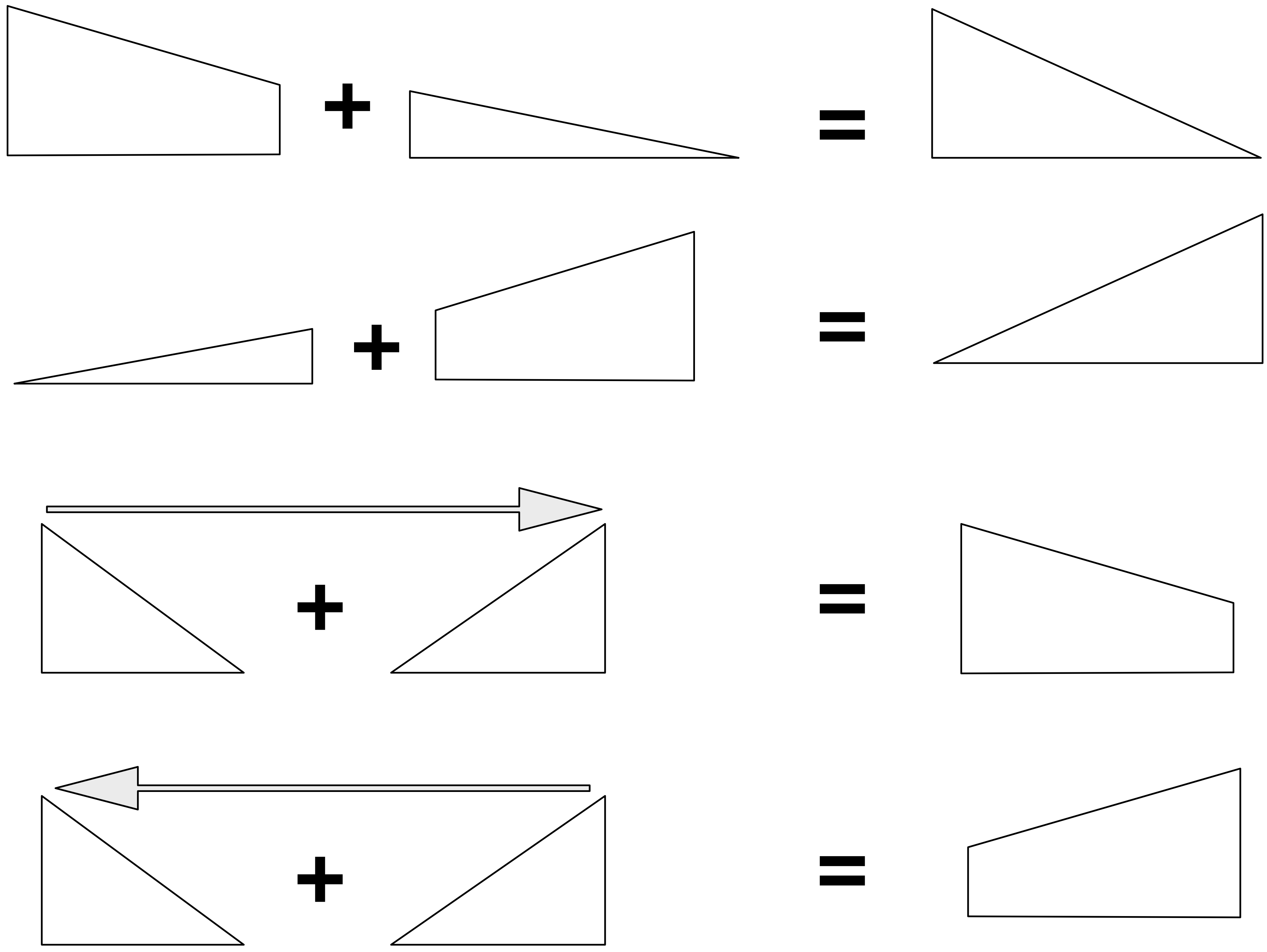


- [min,max,right,no]



Eisner’s algorithm

Possible operations



Pseudo code

```
for each i from 0 to n and all d,c do
  C[i][i][d][c] = 0.0
for each m from 1 to n do
  for each i from 0 to n-m do
    j = i+m
    C[i][j][←][1] = max_{i≤q<j}(C[i][q][→][0] + C[q+1][j][←][0]+score(w_j,w_i)
    C[i][j][→][1] = max_{i≤q<j}(C[i][q][→][0] + C[q+1][j][←][0]+score(w_i,w_j)
    C[i][j][←][0] = max_{i≤q<j}(C[i][q][←][0] + C[q][j][←][1])
    C[i][j][→][0] = max_{i≤q<j}(C[i][q][→][1] + C[q][j][→][0])
return [0][n][→][0]
```

Summary

- Eisner’s algorithm is an improvement over Collin’s algorithm that runs in time $O(|w|^3)$.
- The same scoring model can be used.
- The same technique for extending the parser to labeled parsing can be used, adding $O(|L||w|^2)$ to the run time.
- Eisner’s algorithm is the basis of current arc-factored dependency parsers.

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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 attachment score is normally used

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Accuracy vs precision/recall

- Attachment score is an accuracy score
- For phrase-structure parsing we reported precision and recall
- Why is that not done for dependency parsing?

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Own work

- Deadline assignment 1+2 today
- Next, and last, lecture: Dec 13, 10-12
- Start looking at the dependency assignments!
- Start looking at the seminar article
- Plan your workload for your two courses early, and remember to plan for holidays as well!