Chart Parsing

Parsing
ISCL-BA-06

Çağrı Çöltekin
ccoltekin@sfs.uni-tuebingen.de

University of Tübingen
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Parsing so far

- We can formulate parsing as
  - Top-down: begin with the start symbol, try to *produce* the input string to be parsed
  - Bottom up: begin with the input, and try to *reduce* it to the start symbol
- For both options, we have seen examples of chart parser
- Parsing can also be *directional* or *non-directional*
- In this lecture, we introduce a general mechanism for chart parsing that has all these forms of parsing methods as special cases

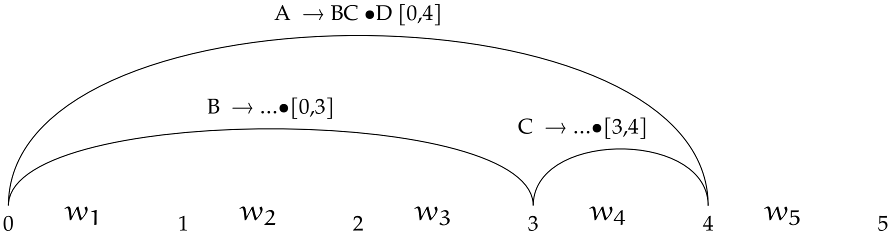
The overall idea

- We adopt Early-like chart entries of the form: $X \rightarrow \alpha \bullet \beta$ `[i,j]` where,
  - i and j are indexes starting from 0 (0 indicating beginning of the input string)
  - The chart entry indicates α is found between i and j, we are looking for a β starting from j
- At any time, we have two sets of items:

active items are those we expect to complete

inactive items are those with a dot at the end

- The goal is to complete $S \rightarrow \ldots\bullet$ `[0,n]`



Components of a typical chart parsing algorithm

- Besides the chart, we keep an *agenda* of 'unexplored items'
- A set of inference rules determine how to modify the chart when processing items from the agenda
- Typically inference rules are similar to completion process of Earley parser
- The following inference rule is part of every chart parser (so-called 'fundamental rule' of chart parsing)
  - If there is an inactive item of the form $\mathtt{A} \rightarrow \alpha\bullet$ and an active item of the form $\mathtt{B} \rightarrow \beta\bullet\mathtt{A}\gamma$ add item $\mathtt{B} \rightarrow \beta\mathtt{A}\bullet\gamma$
- We also need a strategy for selecting the items from the agenda and applying the inference rules
- Depending on the data structure used for the agenda, and order of processing of inference rules, we may get different types of parsers

The sketch of a chart parsing algorithm

```
Initialize $A$ (agenda) and $C$ (chart)
repeat
    $i \leftarrow \mathrm{next}(A)$
    if $i \in C$ then
        discard $i$
    else
        apply all inference rules to $i$
        place new items in $A$
        place the item in $C$
until $A$ is empty
```

- Very simple, but unspecified parts:
  - Initialization
  - Inference rules
  - The order of items received from the agenda
- An item is put into chart only after all inferences from it are in the chart or in the agenda
- Chart is a set, items do not repeat

Bottom-up chart parsing

- Single additional inference rule:
  - If a new item has the form $\mathtt{A} \longrightarrow \alpha\bullet$, add $\mathtt{B} \longrightarrow \mathtt{A}\bullet\beta$ for each rule $\mathtt{B} \longrightarrow \mathtt{A}\beta$ in the grammar.
- Initialization:
  - Empty chart
  - Place $\mathtt{P} \longrightarrow \mathtt{w_i}\ \ \mathtt{[i-1,i]}$ in the agenda for all word w_i (‘P’ is the pre-terminal symbol, typically the POS tag in CL)
  - if there are ϵ rules, add $\mathtt{P} \longrightarrow \bullet\mathtt{[i,i]}$ for all $\mathtt{P} \longrightarrow \epsilon$ in the grammar, for $\mathtt{i}$ in $[0, n]$
- Choice of agenda does not matter. A stack is typical, but a queue or a priority queue is also an option

Example: bottom-up chart parsing

grammar

S → NP VP
NP → Prn N
NP → Prn
VP → V NP
VP → V
VP → V S
Prn → I
Prn → her
V → saw
N → duck
V → duck

stack

`Prn → I• [0,1]`

`V → saw• [1,2]`

`Prn → her• [2,3]`

`N → duck• [3,4]`

0 I 1 saw 2 her 3 duck 4

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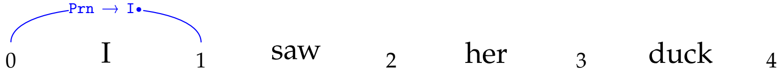

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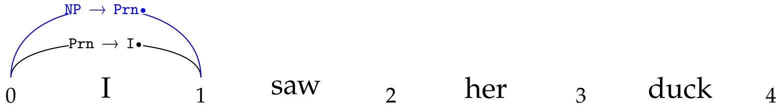
stack

```
S → NP•VP [0,1]
NP → Prn•N [0,1]
V → saw• [1,2]
Prn → her• [2,3]
N → duck• [3,4]
```



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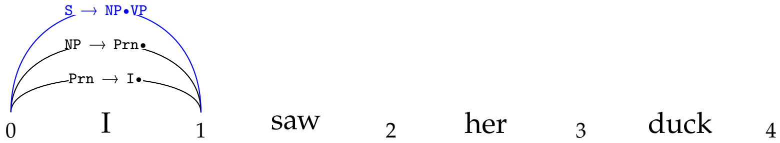

stack

NP → Prn•N [0,1]
V → saw• [1,2]
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V → saw• [1,2]
Prn → her• [2,3]
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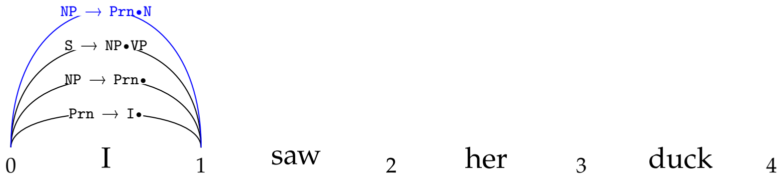

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stack

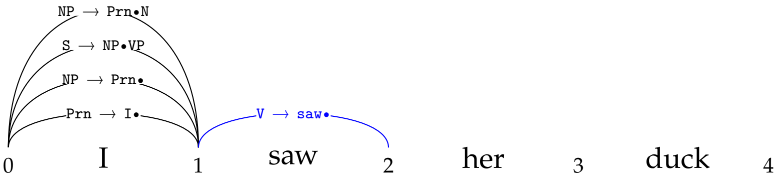
VP → V•S [1,2]

VP → V•NP [1,2]

VP → V• [1,2]

Prn → her• [2,3]

N → duck• [3,4]



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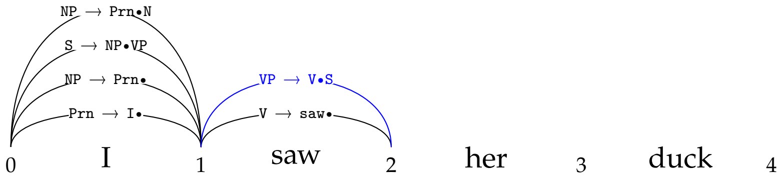

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stack

VP → V•NP [1,2]
VP → V• [1,2]
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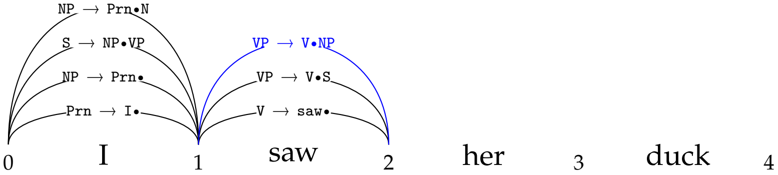

stack

VP → V• [1,2]
Prn → her• [2,3]
N → duck• [3,4]

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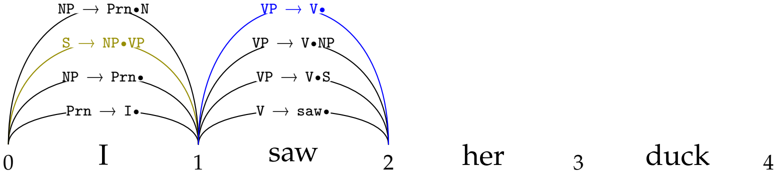

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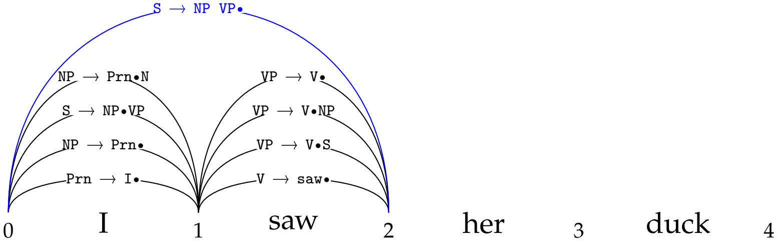

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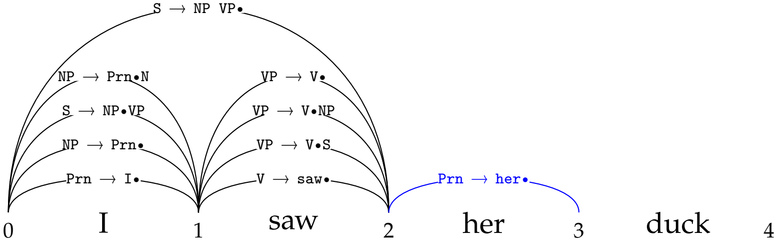

stack

NP → Prn•N [2,3]
N → Prn• [2,3]
N → duck• [3,4]

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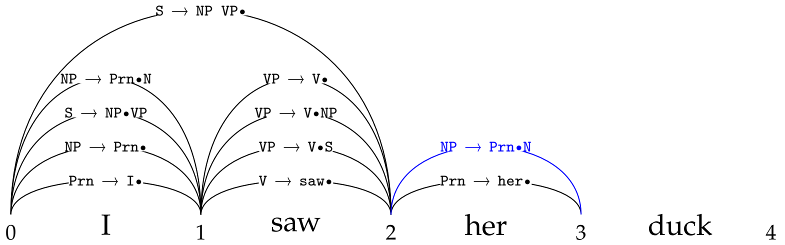

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N → Prn• [2,3]
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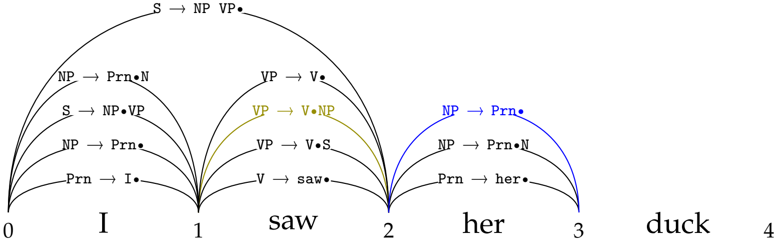

stack

VP → V NP• [1,3]
S → NP•VP [2,3]
N → duck• [3,4]

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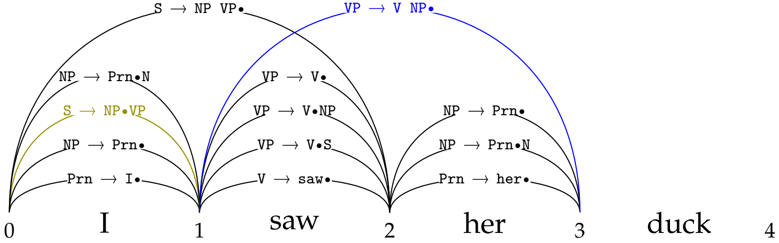

stack

S → NP VP• [0,3]
S → NP•VP [2,3]
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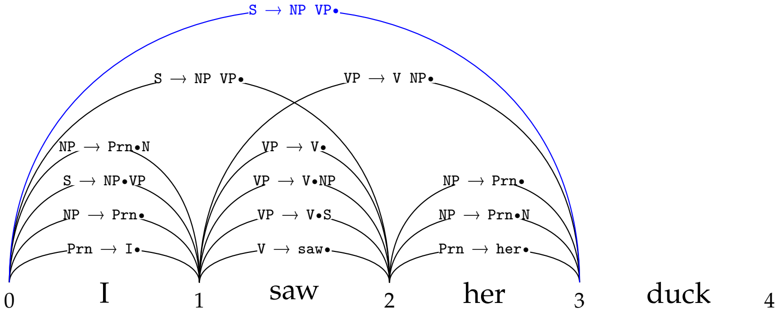
Example: bottom-up chart parsing



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S → NP•VP [2,3]
N → duck• [3,4]

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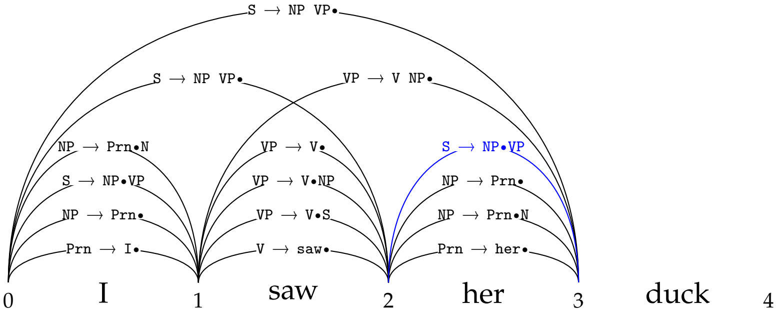

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N → duck• [3,4]

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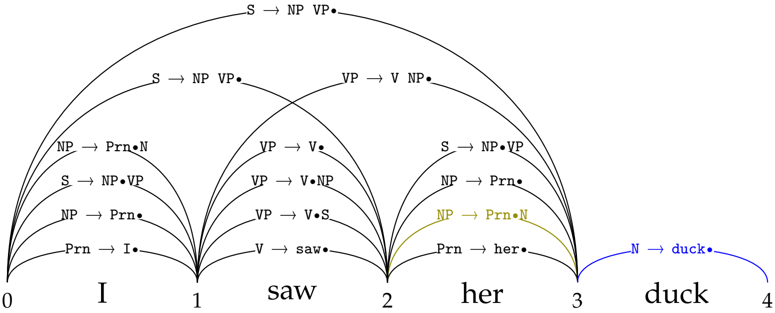

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NP → Prn N• [2,4]

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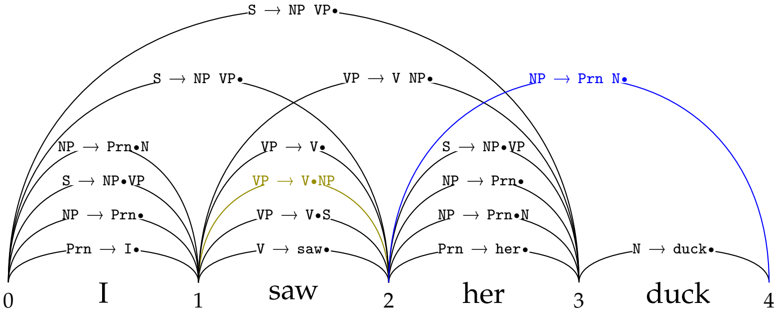

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NP → Prn
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VP → V S
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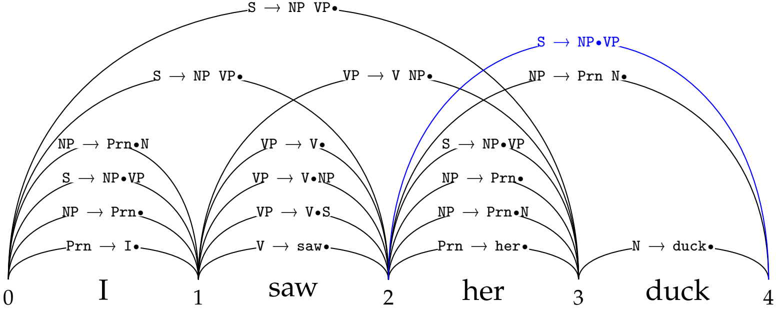
V → duck

stack

S → NP•VP [2,4]
VP → V NP• [1,4]

Example: bottom-up chart parsing



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VP → V NP• [1,4]

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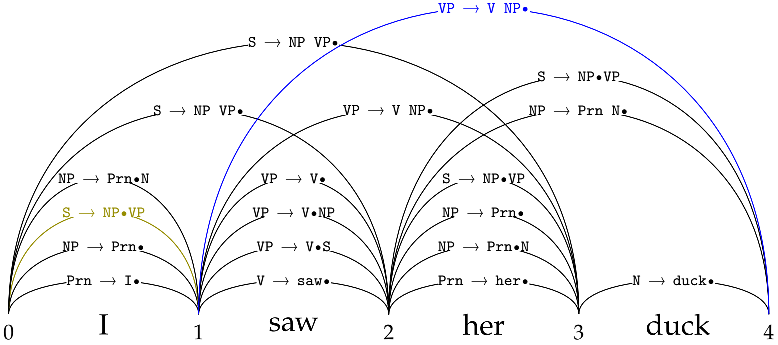

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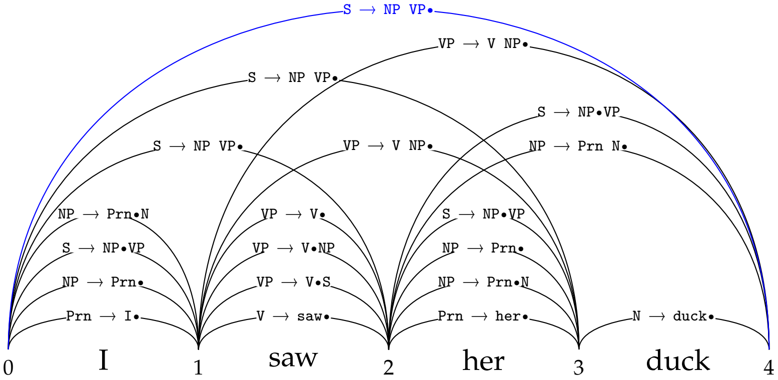

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stack

Bottom-up chart parsing

additional remarks

- The parser (as described) proceeds bottom up (left-corner)
- It can process arbitrary CF grammars
- Stack-based agenda is common, queue-based agenda is rarely used
- An interesting alternative is so-called *head-corner* parsing: using a priority queue (e.g., processing 'heads' first) one can build the 'important' parts of the tree first
- The time complexity is $O(n^3)$
- There are many variants, optimizations (based on, different inference rules, processing strategies)

Top-down chart parsing

- The basic algorithm is the same, but we specify
  - Inference rule (besides the 'fundamental rule'):
    - If the new edge has the form $\mathtt{A} \longrightarrow \alpha\bullet\mathtt{B}\beta$ `[i,j]`, add $\mathtt{B} \longrightarrow \bullet\gamma$ `[j,j]` for each rule $\mathrm{B} \longrightarrow \gamma$ in the grammar.
  - Initialization
    - Empty chart
    - Push $\longrightarrow \bullet\mathtt{S}$ `[0,0]` into the stack
    - Push all productions for the terminal symbols to the stack (or to the chart, as there is nothing to predict for these productions)
  - Typically we use a stack as an agenda

Example: top-down chart parsing

Left as an exercise ;-)

grammar

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Prn → her
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stack

0 I 1 saw 2 her 3 duck 4

Top-down chart parsing

additional remarks

- The parser (as described) is purely top-down
- In practice, it is common to use ‘lookup’
- Stack-based agenda is common, que-based agenda is rarely used
- The time complexity is $O(n^3)$
- There are many variants, optimizations (based on, different inference rules, processing strategies)

Summary

- Chart parsing is a general framework for constructing a variety of parsers
- It shares many similarities with the CKY and Earley

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- Chart parsing is a general framework for constructing a variety of parsers
- It shares many similarities with the CKY and Earley

Next:

- Deterministic parsing (maybe after the break)

Acknowledgments, references, additional reading material

Grune, Dick and Ceriel J.H. Jacobs (2007). *Parsing Techniques: A Practical Guide*. second. Monographs in Computer Science. The first edition is available at `http://dickgrune.com/Books/PTAPG_1st_Edition/BookBody.pdf`. Springer New York. ISBN: 9780387689548.

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Example: top-down chart parsing

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