Grammar and Lexicon

Grammar:
1. \( S \rightarrow NP \ VP \)
2. \( NP \rightarrow ART \ N \)
3. \( NP \rightarrow ART \ ADJ \ N \)
4. \( VP \rightarrow V \ NP \)

Lexicon:
- the: ART
- man: N, V
- old: ADJ, N
- boat: N

Sentence: 1 The 2 old 3 man 4 the 5 boat 6

Efficient Parsing

\( n \) = sentence length

Time complexity for naive algorithm: exponential in \( n \)
Time complexity for bottom-up chart parser: \( \Theta(n^3) \)

Options for improving efficiency:
1. Don’t do twice what you can do once.
2. Don’t represent distinctions that you don’t need.
   
   Fall leaves fall and spring leaves spring.
3. Don’t do once what you can avoid altogether.
   
   The can holds the water. ("can": AUX, V, N)

Earley Algorithm: Top-Down Chart Parser

For all \( S \) rules of the form \( S \rightarrow X_1 \ldots X_k \), add a (top-down) edge from 1 to 1 labeled: \( S \rightarrow \circ X_1 \ldots X_k \).

Do until there is no input left:
1. If the agenda is empty, look up word categories for next word, add to agenda.
2. Select a constituent from the agenda: constituent \( C \) from \( p_1 \) to \( p_2 \).
3. Using the (bottom-up) edge extension algorithm, combine \( C \) with every active edge on the chart (adding \( C \) to chart as well). Add any new constituents to the agenda.
4. For any active edges created in Step 3, add them to the chart using the top-down edge introduction algorithm.
Top-down edge introduction.

To add an edge $S \rightarrow C_1 \ldots \circ C_i \ldots C_n$ ending at position $j$:

For each rule in the grammar of form $C_i \rightarrow X_1 \ldots X_k$,
recursively add the new edge $C_i \rightarrow \circ X_1 \ldots X_k$ from $j$ to $j$.

Grammar and Lexicon

<table>
<thead>
<tr>
<th>Grammar</th>
<th>Lexicon</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S \rightarrow$ NP VP</td>
<td>the: ART</td>
</tr>
<tr>
<td>NP $\rightarrow$ ART ADJ N</td>
<td>large: ADJ</td>
</tr>
<tr>
<td>NP $\rightarrow$ ART N</td>
<td>can: N, AUX, V</td>
</tr>
<tr>
<td>NP $\rightarrow$ ADJ N</td>
<td>hold: N, V</td>
</tr>
<tr>
<td>VP $\rightarrow$ AUX VP</td>
<td>water: N, V</td>
</tr>
<tr>
<td>VP $\rightarrow$ V NP</td>
<td></td>
</tr>
</tbody>
</table>

Sentence: 1 The 2 large 3 can 4 can 5 hold 6 water 7