11-711 Algorithms for NLP

GLR Parsing

Reading:

Tomita,

"An Efficient Augmented Context-Free Parsing Algorithm"

Computational Linguistics 13(1-2), pp. 31–46

GLR Parsing

Goal:

- Extend LR Parsing to handle general CFGs - including ambiguous grammars
- Make the LR Parsing techniques applicable to parsing NL
- Preserve the efficiency of the LR approach as much as possible

General Method:

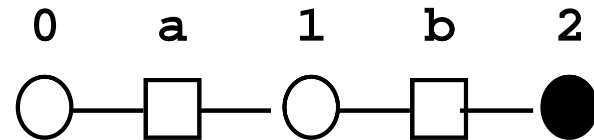
- Extend the LR parsing algorithm to handle conflicting actions
- Use the constructed LR tables as is - usually SLR table
- Pursue in a “pseudo-parallel” fashion all possible parsing actions
- The “closer” the grammar is to being LR - the fewer conflicts - the closer to linear the performance

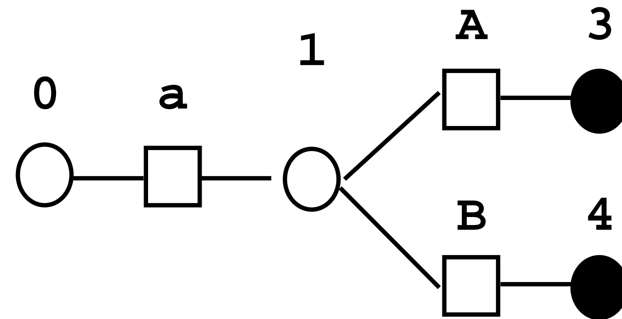
The Graph Structured Stack

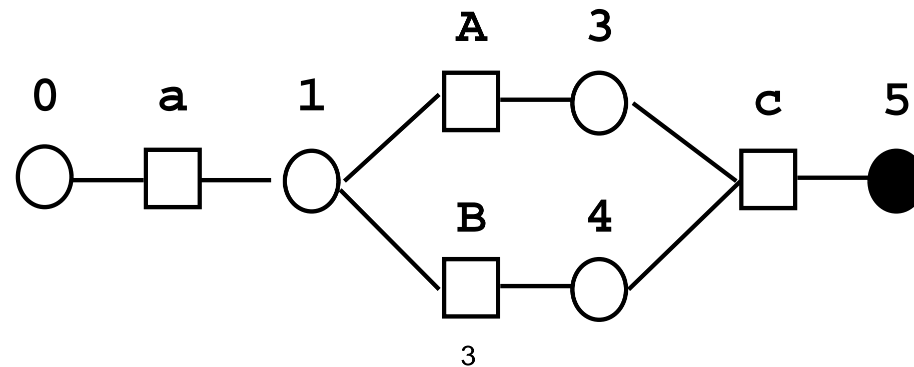
- Compact representation of a set of LR stacks
- Contains state nodes and symbol nodes (like an LR stack)
- Initial state of parser is at the “bottom” of the GSS.
- Each path from the “bottom” of the GSS to a leaf node corresponds to an LR stack
- GSS contains a *set* of active state nodes
- **Splitting the Stack:**
  - When the parsing table specifies multiple actions, the GSS is split into separate branches, each of which pursues one of the actions
- **Merging Branches:**
  - When separate branches of the GSS end in identical active states, they are merged back together
  - Merging allows efficient pursuit of further actions of the parser that are common to the branches

The Graph Structured Stack

Examples of Splitting and Merging of the GSS:







The GLR Parsing Algorithm

- The Algorithm operates in *Stages* - each processing a single input word
- Each stage consists of three *Phases*:
  - **Reduce Phase:** Perform all Reduce actions defined on the set of active state nodes
  - **Shift Phase:** Perform all Shift actions defined on the set of active state nodes
  - **Merge Phase:** Merge active state nodes that have same state

The GLR Parsing Algorithm

The Algorithm in Pseudo-code:

```
   ip = 1
   active = {s_0}
   while (ip <= (n+1)) do
      a = the input word pointed by ip

      if active is empty then return with ''Error''

      if ip = (n+1) then
      If for every s in active action[s,a] = Accept
        then return with ''Accept''
        else return with ''Reject''

\* Reduce Phase: *\
      for every s in active:
      if action[s,a] = Reduce by (rule-i: A-->Beta) then:
```

```
      find all paths p in the GSS of length 2*|Beta|
      for each path p:
         Pop the 2*|Beta| elements from the path
           and reveal state s’
         Push A on top of s’ and then the state
           s’’ = goto[s’,A]
         Add s’’ to active

\* Shift Phase: *\
    for every s in active:
    if action[s,a] = Shift s’ then:
      Push a on top of s and then the state s’
      Add s’ to active

\* Merge Phase: *\
    For every pair of state nodes s and s’ in active
      if state s = state s’ then merge them

    ip = ip+1
```

Efficient Ambiguity Representation

- **Sub-tree Sharing:**
  - Sharing of common sub-trees between full parse trees
  - Symbols in the GSS contain *pointers* to parse tree constituents
  - Whenever a constituent participates in more than one reduction, the same pointer is used
- **Local Ambiguity Packing:**
  - A *Local Ambiguity* - substring analyzable as a constituent A in more than one way
  - Represented in the GSS as two similarly labeled symbol nodes sharing the same state nodes on both sides
  - A procedure can detect these situations and pack the nodes by:
    (1) Creating a single parse node corresponding to the constituent
    (2) Collapsing the two GSS paths into a single path

Efficient Ambiguity Representation

Examples:

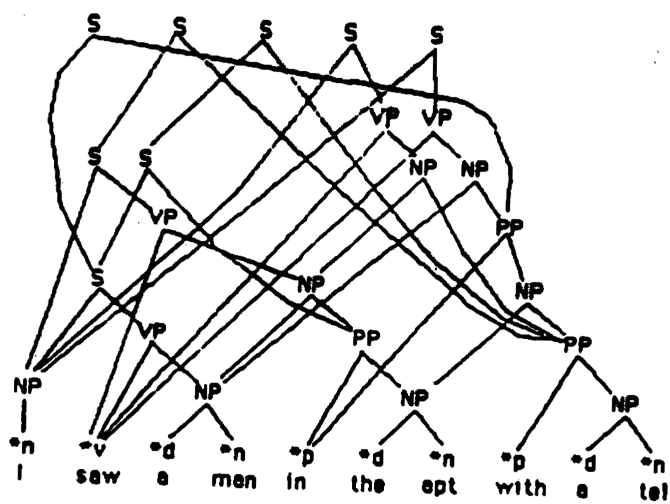


Figure 3.1. Unpacked shared forest.

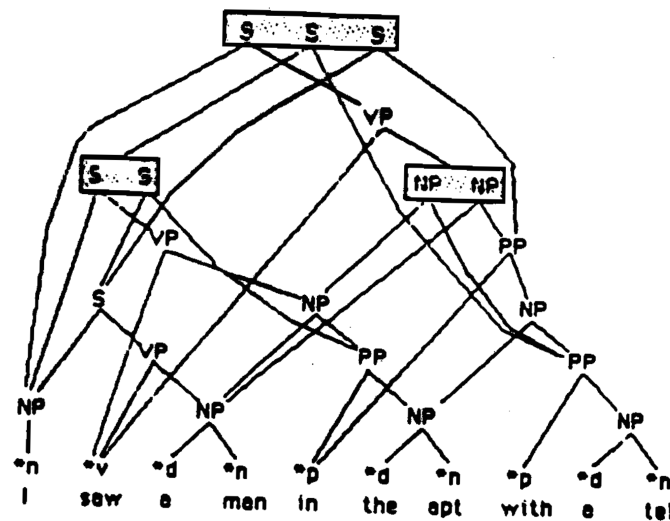


Figure 3.2. Packed shared forest.

GLR Parsing - Example

The Grammar:

$$
\begin{array}{rrcl}
(1) & S & \rightarrow & NP\,VP \\
(2) & S & \rightarrow & S\ PP \\
(3) & NP & \rightarrow & n \\
(4) & NP & \rightarrow & det\ \ n \\
(5) & NP & \rightarrow & NP\ PP \\
(6) & PP & \rightarrow & prep\ NP \\
(7) & VP & \rightarrow & v\ NP
\end{array}
$$

The original input: " $x =$ I saw a man in the park with a telescope"
POS assigned input: " $x =$ n v det n prep det n prep det n"
Parser input: " $x =$ n v det n prep det n prep det n $"

GLR Parsing - Example

Constructed Parsing Table for the Grammar:

State	*det	*n	*v	*prep	$	NP	PP	VP	S
0	sh3	sh4				2			1
1				sh6	acc		5		
2			sh7	sh6			9	8	
3		sh10							
4			re3	re3	re3				
5				re2	re2				
6	sh3	sh4				11			
7	sh3	sh4				12			
8				re1	re1				
9			re5	re5	re5				
10			re4	re4	re4				
11			re6	re6,sh6	re6		9		
12				re7,sh6	re7		9		

Figure 2.2. LR parsing table with multiple entries.

GLR Parsing - Example

Parser input: “ $x =$ n v det n prep det n prep det n $”

Handling Multi POS Words

- When we have a POS ambiguity for a word - handle as a "shift-shift" table conflict: perform multiple shift actions
- Top-down prediction constraints that are implicit in the parser states restrict the set of possible POS at any point in the parsing of an input
- Paths that pursue a POS that is grammatically inconsistant with later portions of the input are eliminated during parsing
- Similar in principle to the way this can be done with Earley
- See example in Tomita article
- Unknown words can be handled similarly - assume the word can have any possible POS (allowed by the current state)

Time Complexity of the GLR Parser

- Time complexity analysis is not straightforward
- Main factor is the number of reduce operations per stage
- Worst-case time bound for general CFGs is $O(n^{p+1})$ where p is the length of the longest grammar rule
- Inferior to Earley and Chart Parser
- Modified version of GLR can do recognition in $O(n^3)$ time
- In practice - GLR time performance is slightly worse than linear with practical large NL grammars
- In comparative evaluations - outperformed both Earley and Chart parsers
- Thus - using GLR is worthwhile:
  NL grammars are “close enough” to being LR