Parsing

Tomita's Parser: Generalized LR Parsing

Laura Kallmeyer

Heinrich-Heine-Universität Düsseldorf

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Motivation

- LR-parsing with one lookahead is deterministic for LR(1) grammars. But there are CFLs that cannot be generated by LR(1)-grammars.
- If a grammar is not LR(1), we can construct a LR(1) parse table with more than one entry in some of the fields. This can be used for non-deterministic parsing.
- However, since we don't have tabulation, partial results get computed several times and the complexity is exponential.
- Tomita's idea: Use a graph-structured stack to avoid computing partial results more than once.

Tomita's parser is an LR parser with tabulation

Graph-structured stack (1)

The stack is a directed acyclic graph (DAG) with the leaves being the topmost elements.

A directed acyclic graph consists of

- A set of nodes (or vertices) V (here finite), and
- a set of edges $E \subset V \times V$, such that
  a) for all $v \in V$: $\langle v, v \rangle \notin E$, and
  b) for every sequence $v_1, \ldots, v_k \in V$ with $\langle v_1, v_2 \rangle, \ldots, \langle v_{k-1}, v_k \rangle \in V$: $v_1 \neq v_k$.

In our case, the vertices of the DAG are labelled with states, non-terminals or terminals.

Graph-structured stack (2)

Our parsing is incremental, i.e., processes the input one by one from left to right.

For every word in the input, before processing that word, we have k possible states.

- We first do the possible reductions for each of the states while leaving the original stack if there is a shift possible. In case of a reduce/reduce or shift/reduce conflict, we branch. If several branches lead to the same states, we identify these.
  We repeat this until no more reductions are possible.

- We then do the possible shifts. Again, if several lead to the same states, we identify these.

Graph-structured stack (3)

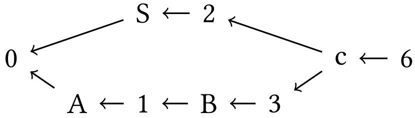
Example: 1. $S \rightarrow AB$, 2. $S \rightarrow SC$, 3. $B \rightarrow BC$,
4. $A \rightarrow a$, 5. $B \rightarrow b$, 6. $C \rightarrow c$

Parse table:

	a	b	c	$\$$	A	B	C	S
0	s4				1			2
1		s5				3		
2			s6	acc			7	
3			r1, s6	r1			8	
4		r4						
5			r5	r5				
6			r6	r6				
7			r2	r2				
8			r3	r3				

Graph-structured stack (4)

For input $w = abcc$, at some point (after shifting the first c) the stack is the following:



Graph-structured stack (5)

Problems (infinite loops) in generalized LR parsing can arise from

- Loops: Productions $A \rightarrow B$, $B \rightarrow A$ would lead to an infinite reduce-loop.
- Hidden left-recursion: $A \rightarrow \alpha A \beta$ with $\alpha \stackrel{*}{\Rightarrow} \epsilon$ would lead to an infinite loop of reducing ϵ to α since $A \rightarrow \alpha \bullet A\beta$ and $A \rightarrow \bullet\alpha A\beta$ would be in the same state.

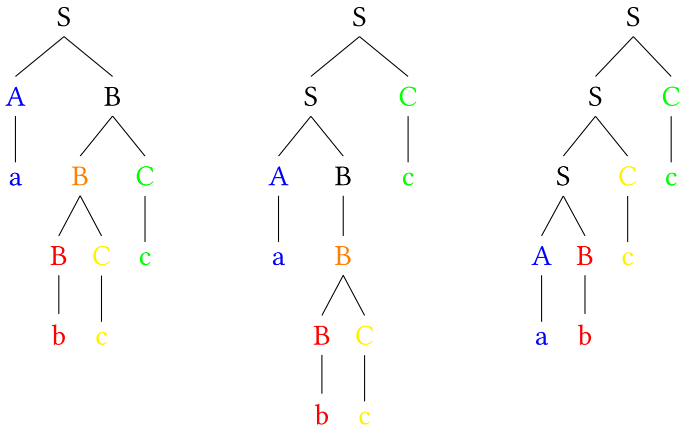
The parse forest (1)

- The dag-structure avoids an explosion in the number of stacks.
- However, we can still have exponentially many parse trees for a given input.
- Therefore, a compact representation of parse forests is needed.
- Tomita uses two techniques: sub-tree sharing and local ambiguity packing.

The parse forest (2)

Example: Take the preceding grammar, $w = abcc$

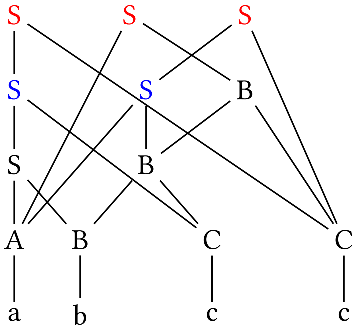
Three parse trees:



Sub-tree sharing: Common sub-trees are represented only once.

The parse forest (3)

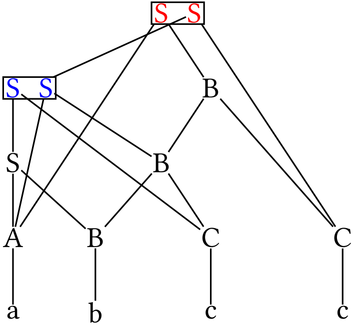
Result of sub-tree sharing:



Local ambiguity packing: whenever the same category spans the same input (possibly with different analyses), the corrponding nodes are put into one packed node.

The parse forest (4)

Result of local ambiguity packing:



The parse forest (5)

Packed parse forests are easy to construct within an LR-parser with graph-structured stack: Whenever a subtree is shared or different subtrees ar packed into one node, there will be a corresponding shared node in the stack graph. More precisely,

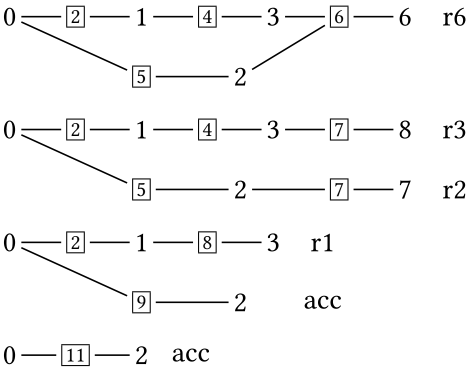
- Whenever a node is shared, we create a shared sub-tree, and
- whenever two or more branches get identified into a single new branch, we create a packed node.

Instead of non-terminals or termnals we use pointers to/identifiers of parse trees as stack vertex labels. This way, in different places we can have pointers to the same parse tree.

The parse forest (6)

Example: $w = abc$.

Stack		analysis
0	s4	
0 — [1] — 4	r4	[1]: a
0 — [2] — 1	s5	[2]: A([1])
0 — [2] — 1 — [3] — 5	r5	[3]: b
0 — [2] — 1 — [4] — 3	r1, s6	[4]: B([3])
0 — [2] — 1 — [4] — 3	s6	
(0 —) [5] — 2	s6	[5]: S([2],[4])



[6]: c

[7]: C([6])

[8]: B([4],[7]), [9]: S([5], [7])

[10]: S([2],[8]), [11]: [[10], [9]]

Conclusion

Tomita's algorithm

- is a general LR(1) parser that works for every CFG;
- uses a graph-structured stack to avoid the explosion otherwise linked to non-determinism;
- uses a compact parse forest representation to avoid the explosion arising from ambiguous grammars.

Reference:

Masaru Tomita (1987) An Efficient Augmented-Context-Free Parsing Algorithm *Computational Linguistics* 13(1–2), 1987.