Compiler Design

CLR and LALR

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Canonical LR Parsing

- Carry extra information in the state so that wrong reductions by $A \rightarrow \alpha$ will be ruled out
- Redefine LR items to include a terminal symbol as a second component (look ahead symbol)
- The general form of the item becomes $[A \rightarrow \alpha.\beta, a]$ which is called LR(1) item.
- Item $[A \rightarrow \alpha., a]$ calls for reduction only if next input is a. The set of symbols "a"s will be a subset of Follow(A).

Closure(I)

repeat

  for each item [A → α.Bβ, a] in I

    for each production B → γ in G'

    and for each terminal b in First(βa)

      add item [B → .γ, b] to I

until no more additions to I

Exercise

- Construct CLR Parse table for the grammar:

  S' → S

  S → L = R

  S → R

  L → *R

  L → id

  R → L

Example

Consider the following grammar

$S' \rightarrow S$
$S \rightarrow CC$
$C \rightarrow cC \mid d$

Compute closure(I) where I={[S' → .S, $]}

$S' \rightarrow .S,$	\$
$S \rightarrow .CC,$	\$
$C \rightarrow .cC,$	c
$C \rightarrow .cC,$	d
$C \rightarrow .d,$	c
$C \rightarrow .d,$	d

Example

Construct sets of LR(1) items for the grammar on previous slide

I_0:	$S' \rightarrow .S,$	$\$$
	$S \rightarrow .CC,$	$\$$
	$C \rightarrow .cC,$	c/d
	$C \rightarrow .d,$	c/d
I_1:	goto(I_0,S)	
	$S' \rightarrow S.,$	$\$$
I_2:	goto(I_0,C)	
	$S \rightarrow C.C,$	$\$$
	$C \rightarrow .cC,$	$\$$
	$C \rightarrow .d,$	$\$$
I_3:	goto(I_0,c)	
	$C \rightarrow c.C,$	c/d
	$C \rightarrow .cC,$	c/d
	$C \rightarrow .d,$	c/d
I_4:	goto(I_0,d)	
	$C \rightarrow d.,$	c/d
I_5:	goto(I_2,C)	
	$S \rightarrow CC.,$	$\$$
I_6:	goto(I_2,c)	
	$C \rightarrow c.C,$	$\$$
	$C \rightarrow .cC,$	$\$$
	$C \rightarrow .d,$	$\$$
I_7:	goto(I_2,d)	
	$C \rightarrow d.,$	$\$$
I_8:	goto(I_3,C)	
	$C \rightarrow cC.,$	c/d
I_9:	goto(I_6,C)	
	$C \rightarrow cC.,$	$\$$

Construction of Canonical LR parse table

- Construct $C=\{I_{0, \ldots,} I_n\}$ the sets of LR(1) items.
- If $[A \rightarrow \alpha.a\beta, b]$ is in I_i and $goto(I_i, a)=I_j$
  then action[i,a]=shift j
- If $[A \rightarrow \alpha., a]$ is in I_i
  then action[i,a] reduce $A \rightarrow \alpha$
- If $[S' \rightarrow S., \$]$ is in I_i
  then action[i,\$] = accept
- If $goto(I_i, A) = I_j$ then goto[i,A] = j for all non terminals A

Parse table

State	c	d	$	S	C
0	s3	s4		1	2
1			acc		
2	s6	s7			5
3	s3	s4			8
4	r3	r3			
5			r1		
6	s6	s7			9
7			r3		
8	r2	r2			
9			r2		

Notes on Canonical LR Parser

- Consider the grammar discussed in the previous two slides. The language specified by the grammar is c*dc*d.
- When reading input cc…dcc…d the parser shifts cs into stack and then goes into state 4 after reading d. It then calls for reduction by C→d if following symbol is c or d.
- IF $ follows the first d then input string is c*d which is not in the language; parser declares an error
- On an error canonical LR parser never makes a wrong shift/reduce move. It immediately declares an error
- Problem: Canonical LR parse table has a large number of states

LALR Parse table

- Look Ahead LR parsers
- Consider a pair of similar looking states (same kernel and different lookaheads) in the set of LR(1) items
  I_4: C → d. , c/d $\qquad$ I_7: C → d., $
- Replace I_4 and I_7 by a new state I_{47} consisting of (C → d., c/d/$)
- Similarly I_3 & I_6 and I_8 & I_9 form pairs
- Merge LR(1) items having the same core

Construct LALR parse table

- Construct $C=\{I_0,......,I_n\}$ set of LR(1) items
- For each core present in LR(1) items find all sets having the same core and replace these sets by their union
- Let $C' = \{J_0,.......,J_m\}$ be the resulting set of items
- Construct action table as was done earlier
- Let $J = I_1 \cup I_2.......\cup I_k$

  since I_1 , I_2......., I_k have same core, goto(J,X) will have the same core

  Let $K=goto(I_1,X) \cup goto(I_2,X)......goto(I_k,X)$ then $goto(J,X)=K$

LALR parse table …

State	c	d	$	S	C
0	s36	s47		1	2
1			acc		
2	s36	s47			5
36	s36	s47			89
47	r3	r3	r3		
5			r1		
89	r2	r2	r2		

Notes on LALR parse table

- Modified parser behaves as original except that it will reduce C→d on inputs like ccd. The error will eventually be caught before any more symbols are shifted.

- In general core is a set of LR(0) items and LR(1) grammar may produce more than one set of items with the same core.

- Merging items never produces shift/reduce conflicts but may produce reduce/reduce conflicts.

- SLR and LALR parse tables have same number of states.

Notes on LALR parse table…

- Merging items may result into conflicts in LALR parsers which did not exist in LR parsers

- New conflicts can not be of shift reduce kind:
  - Assume there is a shift reduce conflict in some state of LALR parser with items
    $\{[X \rightarrow \alpha., a], [Y \rightarrow \gamma.a\beta, b]\}$
  - Then there must have been a state in the LR parser with the same core
  - Contradiction; because LR parser did not have conflicts

- LALR parser can have new reduce-reduce conflicts
  - Assume states
    $\{[X \rightarrow \alpha., a], [Y \rightarrow \beta., b]\}$ and $\{[X \rightarrow \alpha., b], [Y \rightarrow \beta., a]\}$
  - Merging the two states produces
    $\{[X \rightarrow \alpha., a/b], [Y \rightarrow \beta., a/b]\}$

Notes on LALR parse table…

- LALR parsers are not built by first making canonical LR parse tables
- There are direct, complicated but efficient algorithms to develop LALR parsers
- Relative power of various classes
  - $SLR(1) \leq LALR(1) \leq LR(1)$
  - $SLR(k) \leq LALR(k) \leq LR(k)$
  - $LL(k) \leq LR(k)$

Error Recovery

- An error is detected when an entry in the action table is found to be empty.

- Panic mode error recovery can be implemented as follows:

  - scan down the stack until a state **S** with a goto on a particular nonterminal **A** is found.

  - discard zero or more input symbols until a symbol **a** is found that can legitimately follow **A**.

  - stack the state **goto[S,A]** and resume parsing.

- **Choice of A, a:** Normally **A** is chosen from non terminals representing major program pieces such as an expression, statement or a block. For example if **A** is the nonterminal **stmt**, **a** might be **semicolon** or **end**.

Parser Generator

- Some common parser generators
  - YACC: **Y**et **A**nother **C**ompiler **C**ompiler
  - Bison: GNU Software
  - ANTLR: **AN**other **T**ool for **L**anguage **R**ecognition
- Yacc/Bison source program specification (accept LALR grammars)

  declaration

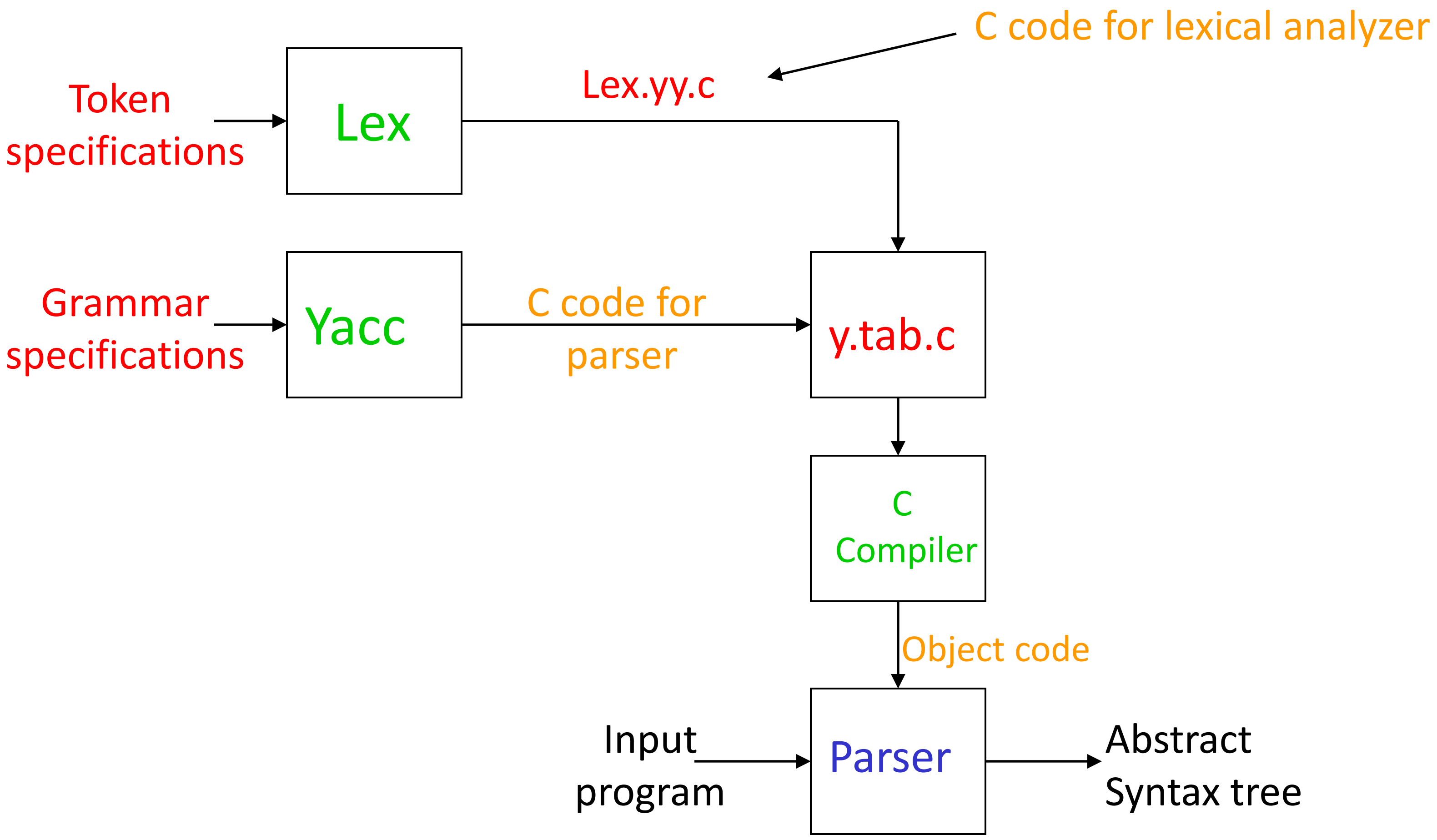
  %%

  translation rules

  %%

  supporting C routines

Yacc and Lex schema



Refer to YACC Manual

Bottom up parsing …

- A more powerful parsing technique
- LR grammars – more expensive than LL
- Can handle left recursive grammars
- Can handle virtually all the programming languages
- Natural expression of programming language syntax
- Automatic generation of parsers (Yacc, Bison etc.)
- Detects errors as soon as possible
- Allows better error recovery