CSE P 501 – Compilers

LR Parser Construction

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Where Do We Stand?

- We have built the LR(0) state machine and parser tables
  - No lookahead yet
  - Different variations of LR parsers add lookahead information, but basic idea of states, closures, and edges remains the same

A Grammar that is not LR(0)

- Build the state machine and parse tables for a simple expression grammar

  $S ::= E\,\$$

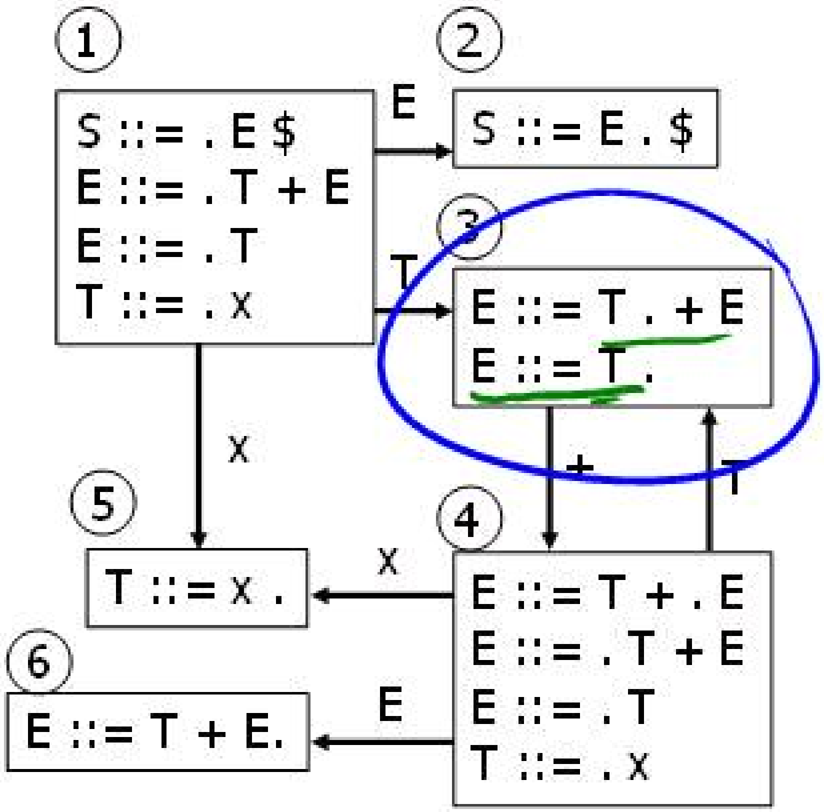
  $E ::= T + E$

  $E ::= T$

  $T ::= \mathrm{x}$

LR(0) Parser for

0. $S ::= E\,\$$
1. $E ::= T + E$
2. $E ::= T$
3. $T ::= x$



	x	+	$	E	T
1	s5			g2	G3
2			acc		
3	r2	s4,r2	r2		
4	s5			g6	G3
5	r3	r3	r3		
6	r1	r1	r1		

- State 3 is has two possible actions on +:

  shift 4 or reduce 2
- ∴ Grammar is not LR(0)

$\rightarrow A + \rightarrow \beta +$

SLR Parsers

- Idea: Use information about what can follow a non-terminal to decide if we should perform a reduction
- Easiest form is SLR – Simple LR
- We need to be able to compute FOLLOW(*A*) – the set of symbols that can follow *A* in any possible derivation
  - i.e., t is in FOLLOW(A) if any derivation contains At
  - To compute this, we need to compute FIRST(γ) for strings γ that can follow *A*

At $\qquad A\gamma$

Calculating FIRST(γ)

- Sounds easy… If $\gamma = X\,Y\,Z$, then FIRST(γ) is FIRST(X), right?
  - But what if we have the rule $X ::= \varepsilon$?
  - In that case, FIRST(γ) includes anything that can follow an X – i.e. FOLLOW(X)

FIRST, FOLLOW, and nullable

- nullable(X) is true if X can derive the empty string
- Given a string γ of terminals and non-terminals, FIRST(γ) is the set of terminals that can begin strings derived from γ.
- FOLLOW(X) is the set of terminals that can immediately follow X in some derivation
- All three of these are computed together

Computing FIRST, FOLLOW, and nullable (1)

- Initialization

  set FIRST and FOLLOW to be empty sets

  set nullable(X) false for all non-terminals X

  set FIRST[a] to a for all terminal symbols a

Computing FIRST, FOLLOW, and nullable (2)

repeat

  for each production $X := Y_1\ Y_2\ \dots\ Y_k$

    if $Y_1 \dots Y_k$ are all nullable (or if $k = 0$)

      set nullable[X] = true

    for each i from 1 to k and each j from i+1 to k

$X ::= \epsilon\epsilon\ Y_3 \text{ -- } Y_k$ first first

      if $Y_1 \dots Y_{i\text{-}1}$ are all nullable (or if $i = 1$)

        add FIRST[Y_i] to FIRST[X]

$X ::= Y_1 Y_2 \text{ -- } Y_i\ \epsilon\epsilon\epsilon$ follow

      if $Y_{i+1} \dots Y_k$ are all nullable (or if $i = k$)

        add FOLLOW[X] to FOLLOW[Y_i]

$Y_i\ \epsilon\epsilon\epsilon\ Y_j$ follow FIRST

      if $Y_{i+1} \dots Y_{j\text{-}1}$ are all nullable (or if i+1=j)

        add FIRST[Y_j] to FOLLOW[Y_i]

Until FIRST, FOLLOW, and nullable do not change

Example

- Grammar

1) $Z ::= d$
2) $Z ::= X\ Y\ Z$
3) $Y ::= \varepsilon$
4) $Y ::= c$
5) $X ::= Y$
6) $X ::= a$

	① nullable	② FIRST	③ FOLLOW
X	~~no~~ yes(5)	a(6), c(5)	c(2), d(2), a(2)
Y	~~no~~ yes(3)	c(4)	d(2), a, c(2)
Z	no	d(1) a(2) c(2)	

LR(0) Reduce Actions

- In an LR(0) parser, if a state contains a reduction, it is unconditional regardless of the next input symbol
- Algorithm:

  Initialize R to empty

  for each state I in T

  for each item $[A ::= \alpha\ .]$ in I

  add $(I, A ::= \alpha)$ to R

SLR Construction

- This is identical to LR(0) – states, etc., except for the calculation of reduce actions
- Algorithm:

  Initialize R to empty

  for each state I in T

    for each item [$A ::= \alpha$.] in I

      [for each terminal a in FOLLOW(A)]

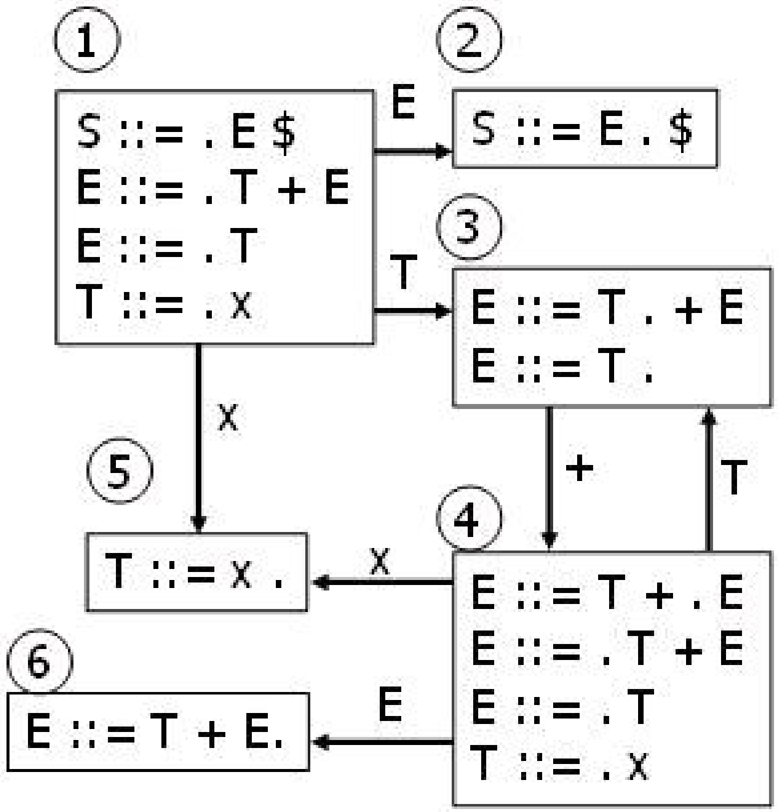
        add (I, a, $A ::= \alpha$) to R

  - i.e., reduce α to A in state I only on lookahead a

T+ Aα

SLR Parser for

0. S ::= E $
1. E ::= T + E
2. E ::= T
3. T ::= x



	x	+	$	E	T
1	s5			g2	g3
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On To LR(1)

- Many practical grammars are SLR
- LR(1) is more powerful yet
- Similar construction, but notion of an item is more complex, incorporating lookahead information

LR(1) Items

$A ::= \alpha\beta$

- An LR(1) item $[A ::= \alpha\ .\ \beta,\ a]$ is
  - A grammar production ($A ::= \alpha\beta$)
  - A right hand side position (the dot)
  - A lookahead symbol (a)
- Idea: This item indicates that α is the top of the stack and the next input is derivable from βa.
- Full construction: see the book

LR(1) Tradeoffs

- LR(1)
  - Pro: extremely precise; largest set of grammars / languages
  - Con: potentially very large parse tables with many states

LALR(1)

- Variation of LR(1), but merge any two states that differ only in lookahead
  - Example: these two would be merged

    [A ::= x . , a]

    [A ::= x . , b]

LALR(1) vs LR(1)

- LALR(1) tables can have many fewer states than LR(1)
- LALR(1) may have reduce conflicts where LR(1) would not (but in practice this doesn't happen often)
- Most practical bottom-up parser tools are LALR(1) (e.g., yacc, bison, CUP)

Language Heirarchies