CSE302: Compiler Design

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Outline

- Recap
  - LR(0) parsing and SLR(1) parsing
- General/Canonical LR(1) parsing
- Lookahead LR(1) / LALR(1) parsing
- Summary and homework

The LR(0) and SLR(1) Parsing Algorithms

- LR(0) parsing
  - If state *s* contains $A \to \alpha.X\beta$ where *X* is a terminal, then shift and the state changes to *s'* containing $A \to \alpha X.\beta$
  - If state *s* contains $A \to \gamma.$, then reduce by $A \to \gamma$ (stack ops) and the state changes to *s'* containing $B \to \lambda A.\eta$
- SLR(1) parsing
  - If state *s* contains $A \to \alpha.X\beta$ where *X* is a terminal, and the lookahead token is *X*, then shift and the state changes to *s'* containing $A \to \alpha X.\beta$
  - If state *s* contains $A \to \gamma.$, and the lookahead token is in FOLLOW(*A*), then reduce by $A \to \gamma$ (stack ops) and the state changes to *s'* containing $B \to \lambda A.\eta$

Another Example

- Another example
  - stmt → call-stmt | assign-stmt
  - call-stmt → **identifier**
  - assign-stmt → var=expr
  - var → **identifier**
  - expr → var | **number**
- Is this an SLR(1) grammar?

Observations

- SLR(1) parsing is more powerful than LR(0) parsing due to its consideration of lookaheads in the parsing process
  - However, the lookaheads are not used in the finite automata construction
- The limit of SLR(1) parsing can be improved if its NFA/DFA construction does not ignore lookaheads

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Finite Automata of Parsing States

- Finite automata for LR(1) parsers
  - LR(1) items are used to identify the parsing states
    - An LR(1) item is a pair consisting of an LR(0) item and a lookahead token
      - $[A \rightarrow \alpha.\beta, a]$
  - NFA construction: transitions b/w LR(1) items
    - Non-ε transitions
      - Given an LR(1) item $[A \rightarrow \alpha.X\beta, a]$, where X is any symbol, there is a transition on X to the item $[A \rightarrow \alpha X.\beta, a]$
    - ε-transitions
      - Given an LR(1) item $[A \rightarrow \alpha.B\gamma, a]$, where B is a nonterminal, there are ε-transitions to items $[B \rightarrow .\beta, b]$ for every production $B \rightarrow \beta$ and for every token b in First(γa)

LR(1) NFA/DFA and Parsing Table Construction Examples

- Grammar
  - $S' \to S$
  - $S \to$ **id** | V=E
  - $V \to$ **id**
  - $E \to V$ | **n**
- NFA construction: transitions between LR(1) items
  - Non-ε transitions
    - Given an LR(1) item [$A \to \alpha.X\beta$, a], where X is any symbol, there is a transition on X to the item [$A \to \alpha X.\beta$, a]
  - ε-transitions
    - Given an LR(1) item [$A \to \alpha.B\gamma$, a], where B is a nonterminal, there are ε-transitions to items [$B \to .\beta$, b] for every production $B \to \beta$ and for every token b in First(γa)
- Input: **id**=**n**

LR(1) Parsing Algorithm

- LR(1) parsing
  - If state s contains $[A \to \alpha.X\beta,a]$ where X is a terminal, and the lookahead token is X, then shift and the state changes to s' containing $[A \to \alpha X.\beta,a]$
  - If state s contains $[A \to \gamma.,a]$, and the lookahead token is a, then reduce by $A \to \gamma$ (stack ops) and the state changes to s' containing $[B \to \lambda A.\eta,b]$
- LR(0) parsing
  - If state s contains $A \to \alpha.X\beta$ where X is a terminal, then shift and the state changes to s' containing $A \to \alpha X.\beta$
  - If state s contains $A \to \gamma.$, then reduce by $A \to \gamma$ (stack ops) and the state changes to s' containing $B \to \lambda A.\eta$
- SLR(1) parsing
  - If state s contains $A \to \alpha.X\beta$ where X is a terminal, and the lookahead token is X, then shift and the state changes to s' containing $A \to \alpha X.\beta$
  - If state s contains $A \to \gamma.$, and the lookahead token is in FOLLOW(A), then reduce by $A \to \gamma$ (stack ops) and the state changes to s' containing $B \to \lambda A.\eta$

Another LR(1) DFA and Parsing Table Construction Examples

- Grammar
  - $A' \rightarrow A$
  - $A \rightarrow (A)$
  - $A \rightarrow$ a
- NFA construction: transitions between LR(1) items
  - Non-ε transitions
    - Given an LR(1) item [$A \rightarrow \alpha.X\beta$, a], where X is any symbol, there is a transition on X to the item [$A \rightarrow \alpha X.\beta$, a]
  - ε-transitions
    - Given an LR(1) item [$A \rightarrow \alpha.B\gamma$, a], where B is a nonterminal, there are ε-transitions to items [$B \rightarrow .\beta$, b] for every production $B \rightarrow \beta$ and for every token b in First(γa)
- Compare the LR(1) DFA with the LR(0) DFA

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Two Principles of LALR(1) Parsing

- The **core** of a state in LR(1) DFA is a state in the LR(0) DFA.
- Given two states s1 and s2 in the LR(1) DFA that have the same core. Suppose there is a transition on X from s1 to a state t1. Then there is also a transition on X from s2 to a state t2, and t1 and t2 have the same core.
- Therefore based on LR(1) DFA, we can transform it to a DFA that is identical to the LR(0) DFA, except that each state consists of items with sets of lookaheads.

Constructing LALR(1) DFA and Parsing Table

- Identifying all states that have the same core and forming the union of the lookaheads for each LR(0) item
- Linking the new states based on the links in the LR(1) DFA
- An example
  - $A' \rightarrow A$
  - $A \rightarrow (A)$
  - $A \rightarrow \text{a}$

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Homework#9 (Due on 03/26)

- Homework #9 assignment has been posted at the Blackboard System.