Compiler design

Lecture 6: Bottom-Up Parsing (EaC§3.4)

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Top-Down Parser

A Top-Down parser builds a derivation by working from the start symbol to the input sentence.

Bottom-Up Parser

A Bottom-Up parser builds a derivation by working from the input sentence back to the start symbol.

Bottom-Up Parsing

Example: CFG

Goal	::=	a A B e
A	::=	A b c
A	::=	b
B	::=	d

Input: abbcde

Bottom-Up Parsing

abbcde

Bottom-Up Parsing

Example: CFG

Goal	::=	a A B e
A	::=	A b c
A	::=	b
B	::=	d

Input: abbcde

Bottom-Up Parsing

abbcde
aAbcde

Bottom-Up Parsing

Example: CFG

Goal	::=	a A B e
A	::=	A b c
A	::=	b
B	::=	d

Input: abbcde

Bottom-Up Parsing

abbcde
aAbcde
aAde

Bottom-Up Parsing

Example: CFG

Goal	::=	a A B e
A	::=	A b c
A	::=	b
B	::=	d

Input: abbcde

Bottom-Up Parsing

abbcde
aAbcde
aAde
aABe

Bottom-Up Parsing

Example: CFG

Goal	::=	a A B e
A	::=	A b c
A	::=	b
B	::=	d

Input: abbcde

Bottom-Up Parsing

abbcde
aAbcde
aAde
aABe
Goal

Bottom-Up Parsing

Example: CFG

Goal	::=	a A B e
A	::=	A b c
A	::=	b
B	::=	d

Input: abbcde

Bottom-Up Parsing

productions ↑

abbcde
aAbcde
aAde
aABe
Goal

↓ reductions

Note that the production follows a rightmost derivation.

Leftmost vs Rightmost derivation

Leftmost vs Rightmost derivation

Example: CFG

Goal ::= a A B e

A ::= A b c | b

B ::= d

Leftmost derivation

Goal
aABe
aAbcBe
abbcBe
abbcde

Rightmost derivation

Goal
aABe
aAde
aAbcde
abbcde

LL parsers

LR parsers

Shift-Reduce Parser

Shift-reduce parser

- It consists of a stack and the input
- It uses four actions:
  1. **shift**: next symbol is shifted onto the stack
  2. **reduce**: pop the symbols $Y_n, \ldots, Y_1$ from the stack that form the right member of a production $X ::= Y_n, \ldots, Y_1$
  3. **accept**: stop parsing and report success
  4. **error**: error reporting routine

How does the parser know when to shift or when to reduce?

Similarly to a top-down parser, could back-track if wrong decision made or look ahead to decide.

Can build a DFA to decide when we should shift or reduce (will not see it in this course).

Shift-reduce parser

Example: CFG

Goal	::=	a A B e
A	::=	A b c | b
B	::=	d

Operation:

Input

abbcde

Stack

Shift-reduce parser

Example: CFG

Goal	::=	a A B e
A	::=	A b c | b
B	::=	d

Operation: shift

Input

bbcde

Stack

a

Shift-reduce parser

Example: CFG

Goal	::=	a A B e
A	::=	A b c | b
B	::=	d

Operation: shift

Input
bcde

Stack
ab

Shift-reduce parser

Example: CFG

Goal	::=	a A B e
A	::=	A b c | b
B	::=	d

Operation:

Input	Stack
bcde	ab

Choice here: shift or reduce?

Can lookahead one symbol to make decision.
(Knowing what to do is not explain here, need to analyse the grammar, see EaC§3.5)

Shift-reduce parser

Example: CFG

Goal	::=	a A B e
A	::=	A b c | b
B	::=	d

Operation: reduce

Input
bcde

Stack
aA

Shift-reduce parser

Example: CFG

Goal	::=	a A B e
A	::=	A b c | b
B	::=	d

Operation: shift

Input
cde

Stack
aAb

Shift-reduce parser

Example: CFG

Goal	::=	a A B e
A	::=	A b c | b
B	::=	d

Operation:

Input	Stack
cde	aAb

Choice here: shift or reduce?

Can lookahead one symbol to make decision.
(Knowing what to do is not explain here, need to analyse the grammar, see EaC§3.5)

Shift-reduce parser

Example: CFG

Goal ::= a A B e

A ::= A b c | b

B ::= d

Operation: shift

Input	Stack
de	aAbc

Shift-reduce parser

Example: CFG

Goal	::=	a A B e
A	::=	A b c | b
B	::=	d

Operation: reduce

Input
de

Stack
aA

Shift-reduce parser

Example: CFG

Goal	::=	a A B e
A	::=	A b c | b
B	::=	d

Operation: shift

Input
e

Stack
aAd

Shift-reduce parser

Example: CFG

Goal	::=	a A B e
A	::=	A b c | b
B	::=	d

Operation: reduce

Input

e

Stack

aAB

Shift-reduce parser

Example: CFG

Goal	::=	a A B e
A	::=	A b c | b
B	::=	d

Operation: shift

Input

Stack

aABe

Shift-reduce parser

Example: CFG

Goal	::=	a A B e
A	::=	A b c | b
B	::=	d

Operation: reduce

Input

Stack

Goal

Top-Down vs Bottom-Up Parsing

Top-Down

- 👍 Easy to write by hand
- 👍 Easy to integrate with the compiler

- 👎 Supports a smaller class of grammars
  - ⇒ cannot handle left recursion in the grammar
- 👎 Recursion might lead to performance issues
  - 👍 Table encoding possible for better performance

Top-Down vs Bottom-Up Parsing

Top-Down

- 👍 Easy to write by hand
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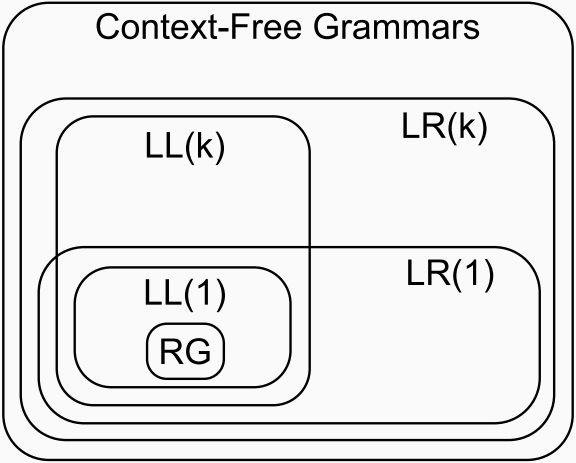
- 👎 Recursion might lead to performance issues
  - 👍 Table encoding possible for better performance

Bottom-Up

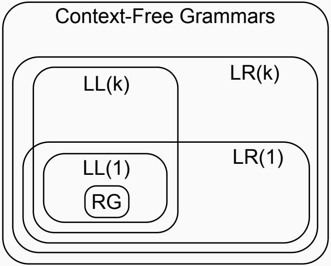
- 👍 Very efficient (no recursion)
- 👍 Supports a larger class of grammar
  - Handles left/right recursion in the grammar

- 👎 Harder to write by hand
  - ⇒Requires generation tools
- 👎 Rigid integration to compiler

Expressive Power of Grammars



Language vs. Grammar



Language $\neq$ Grammar

- A language can be defined by more than one grammar
- These grammars might be of different "complexity" (LL(1), LL(k), LR(k))
- $\Rightarrow$ Language complexity $\neq$ grammar complexity

Real-world examples of parser technology used

Parser generators:

- YACC: bottom up (LR)
- ANTLR: recursive descent (LL)
- JavaCC: recursive descent (LL)

C compilers

- LLVM: hand-written recursive descent parser (LL)
- GCC: started with parser generator (YACC $\Rightarrow$ LR),
  now uses hand-written recursive descent (LL)

Java compilers

- Eclipse compiler frontend:
  auto-generated using Jikes Parser Generator, bottom-up (LR)
- IntelliJ compiler frontend: hand-written recursive descent (LL)
- OpenJDK compiler frontend:
  hand-written recursive descent (LL)
  https://github.com/openjdk/jdk/blob/master/src/jdk.compiler/share/classes/com/sun/tools/javac/parser/JavacParser.java

Next lecture

- Parse tree and abstract syntax tree