Monash University
Faculty of Information Technology

# Lecture 12
# Parsing

Slides by Graham Farr (2017), with some by David Albrecht (2011).

FIT2014 Theory of Computation

# Overview

- Definitions
- Examples
- Shift-reduce parser
- Lex & Yacc

# Parsing

- Suppose you have a Context Free Grammar, and a string of letters.
- **Parsing:** determining whether the string
  - is a word in the language, and if it is,
  - finding a **parse tree**, or a **derivation**, for it.
- **Parser:** a program that does this.
- Two main types:
  - **Top-down parsers**
  - **Bottom-up parsers**
    - **reduce** the string to the Start symbol
    - repeatedly apply production rules in reverse

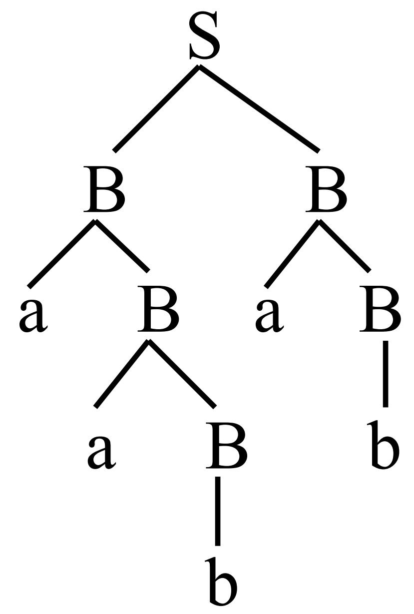
# a*ba*b

**S → BB**

**B → aB**

**B → b**

**Input: aabab**

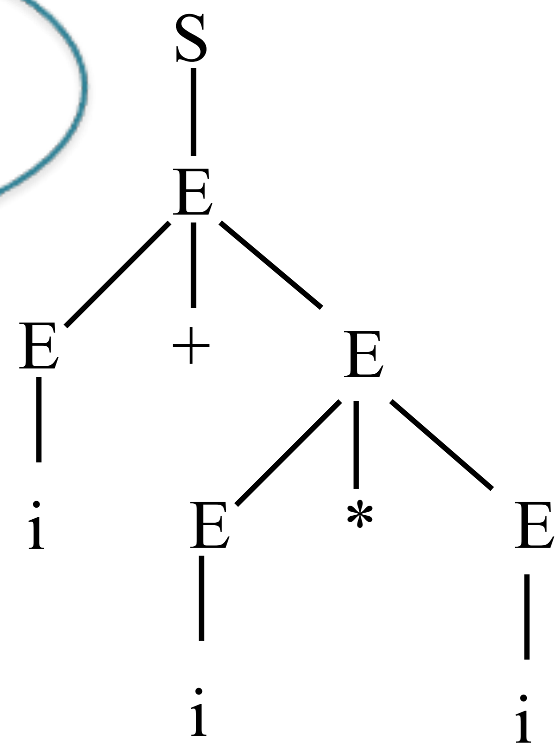


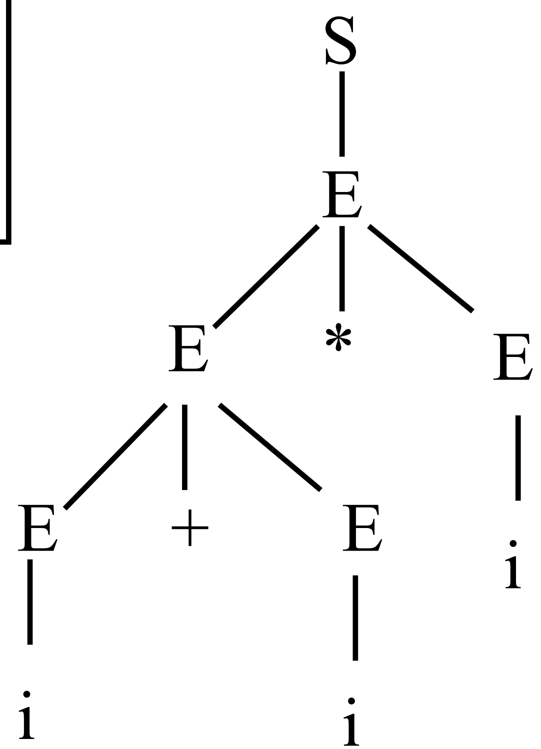
# Plus-Times-A

**Input: i + i*i**

| | |
|---|---|
| **S → E** | **(1)** |
| **E → E + E** | **(2)** |
| **E → E * E** | **(3)** |
| **E → i** | **(4)** |

Two parse trees …




This grammar is **ambiguous**.

# Plus-Times-B

**S → E**

**E → T + E**

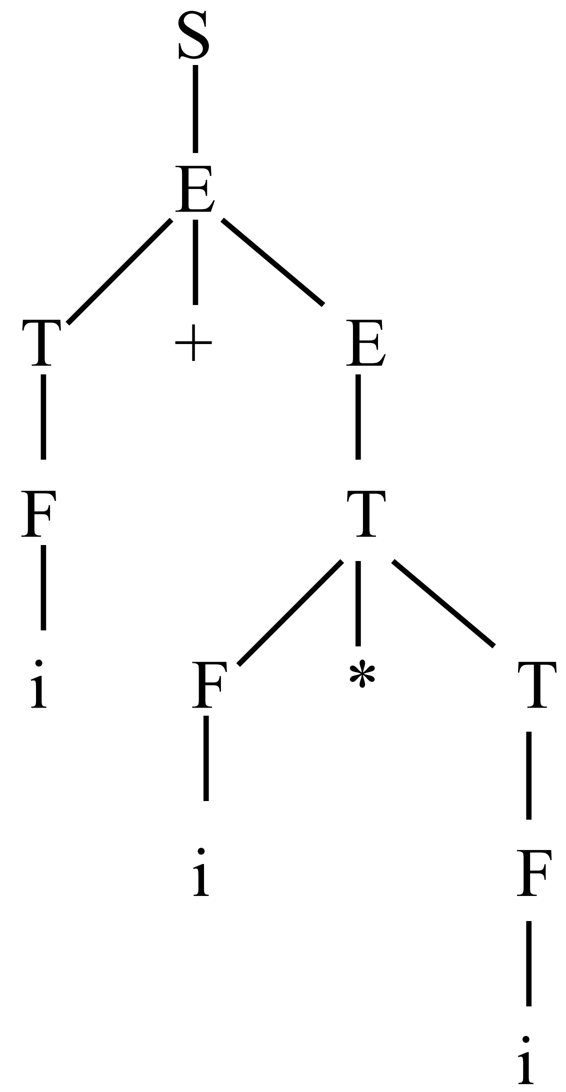
**E → T**

**T → F * T**

**T → F**

**F → i**

**Input: i + i*i**



# LR Parser

- Bottom-up Parser
- Scan input **L**eft to Right
- Construct a **R**ightmost derivation in reverse
- Implemented using a Deterministic Pushdown Automaton (DPDA).
- Not all CFGs have one: DCFL $\neq$ CFL
- We'll look at one type of LR parser: **shift-reduce parser**

# Shift-reduce Parser

- a particular type of LR Parser
- Has:
  - a **stack:** terminals and non-terminals processed so far, and
  - a **buffer:** the rest of the input string (yet to be processed)
- Initially:
  - Stack is empty
  - Buffer contains the entire input string
- Repeatedly …
  - **Shift** input letters onto the stack, *OR*
  - When a string of top-most stack symbols equal the right-hand side of a production rule:
    - **Reduce** that string, i.e., use production rule in reverse
- ... until Stack only has Start symbol, and Buffer is empty.

# a*ba*b

| | | |
|---|---|---|
| $S \rightarrow BB$ | | (1) |
| $B \rightarrow aB$ | | (2) |
| $B \rightarrow b$ | | (3) |

**Input: abb**

| | | |
|---|---|---|
| | abb | shift |
| a | bb | shift |
| ab | b | reduce, (3) |
| aB | b | reduce, (2) |
| B | b | shift |
| Bb | | reduce, (3) |
| BB | | reduce, (1) |
| S | | ACCEPT |

# Plus-Times-A

**Input: i + i*i**

$$S \rightarrow E \quad (1)$$
$$E \rightarrow E + E \quad (2)$$
$$E \rightarrow E * E \quad (3)$$
$$E \rightarrow i \quad (4)$$

| | | |
|---|---|---|
| | i+i*i | shift |
| i | +i*i | reduce, (4) |
| E | +i*i | shift |
| E+ | i*i | shift |
| E+i | *i | reduce, (4) |
| E+E | *i | |

*To **shift**, or to **reduce**?*

# Plus-Times-A

**Input: i + i*i**

| | |
|---|---|
| $S \rightarrow E$ | (1) |
| $E \rightarrow E + E$ | (2) |
| $E \rightarrow E * E$ | (3) |
| $E \rightarrow i$ | (4) |

| | | |
|---|---|---|
| | i+i*i | shift |
| i | +i*i | reduce, (4) |
| E | +i*i | shift |
| E+ | i*i | shift |
| E+i | *i | reduce, (4) |
| E+E | *i | shift |
| E+E* | i | shift |
| E+E*i | | reduce, (4) |
| E+E*E | | reduce, (3) |
| E+E | | reduce, (2) |
| E | | reduce, (1) |
| S | | ACCEPT |

# Plus-Times-A

**Input: i + i*i**

$S \rightarrow E$ (1)

$E \rightarrow E + E$ (2)

$E \rightarrow E * E$ (3)

$E \rightarrow i$ (4)

| | | |
|---|---|---|
| | i+i*i | shift |
| i | +i*i | reduce, (4) |
| E | +i*i | shift |
| E+ | i*i | shift |
| E+i | *i | reduce, (4) |
| E+E | *i | |

*To **shift**, or to **reduce**?*

# Plus-Times-A

**Input: i + i*i**

| | | |
|---|---|---|
| | $S \rightarrow E$ | (1) |
| | $E \rightarrow E + E$ | (2) |
| | $E \rightarrow E * E$ | (3) |
| | $E \rightarrow i$ | (4) |

| | | |
|---|---|---|
| | i+i*i | shift |
| i | +i*i | reduce, (4) |
| E | +i*i | shift |
| E+ | i*i | shift |
| E+i | *i | reduce, (4) |
| E+E | *i | reduce, (2) |
| E | *i | shift |
| E* | i | shift |
| E*i | | reduce, (4) |
| E*E | | reduce, (3) |
| E | | reduce, (1) |
| S | | ACCEPT |

→ **shift-reduce conflict.**

Also: **reduce-reduce conflict**: letters on top of stack correspond to more than one production rule.

# Yacc

- **Y**et **A**nother **C**ompiler-**C**ompiler
- A **parser-generator**
- Input: a Context-Free Grammar …
- Output: parser, in file **`y.tab.c`**
- Typically used with a lexical analyser, e.g., **Lex**.

# Lex

- **Lex**ical Analyser
- Input: regular expression for each token …
- Output: lexical analyser, in file **`lex.yy.c`**

- Both are widely available in Unix/Linux

# Lex: lexical analysis

filename.l

```
definitions …
%%
regexps + code, for each token …
%%
C code …
```

lex

lex.yy.c

```
…… yylex() ……
```

# Yacc: parser generation

Filename.y

```
   declarations (incl. token names) …
%%
   Grammar: production rules …
%%
   C code …
```

↓

yacc

↓

y.tab.c

```
…… yyparse() ……
```

calls yylex()
to get tokens

# Lex & Yacc

- Compile **`y.tab.c`** and **`lex.yy.c`** using, say, **`cc`**.
- Obtain an executable parser.
- It can evaluate as it parses.
- See Assignment 2.

- Conflict resolution in Yacc:
  - Shift-reduce: shift
  - Reduce-reduce: use the rule listed first.

# Revision

- Construct a parse tree for given string and grammar.
- Understand how a Shift-reduce Parser works.
- Start using Lex and Yacc.