CFG2: Ambiguity

Context-Free Grammars

CMPT 379: Compilers

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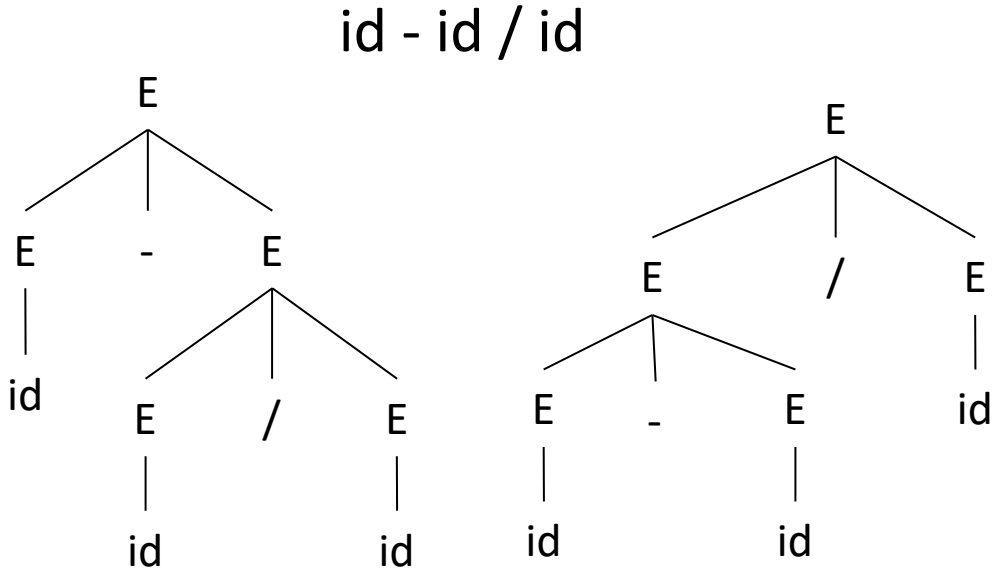
Ambiguity

r1	E → E - E
r2	E → E / E
r3	E → (E)
r4	E → id



Ambiguity

- Grammar is ambiguous if more than one parse tree is possible for some sentences
  - There is more than one leftmost (or rightmost) derivations
- Ambiguity is not acceptable in programming languages
  - Leaves meaning of some programs ill-defined
  - Unfortunately, it's undecidable to check whether a given CFG is ambiguous
  - Some CFLs are inherently ambiguous (do not have an unambiguous CFG)

Ambiguity

- Handle ambiguity:
  - Rewrite the grammar unambiguously
  - Augment parser by enforcing precedence and associativity
- Consider the original ambiguous grammar:

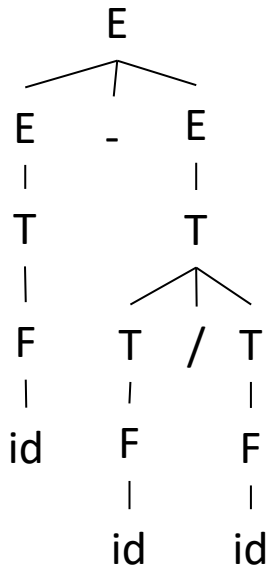
  $E \rightarrow E - E$ $\quad E \rightarrow E / E$

  $E \rightarrow (E)$ $\quad E \rightarrow$ **id**
- How can we change the grammar to get only one tree for the input string: **id - id / id**

Precedence

- Original ambiguous grammar:
  - $E \rightarrow E - E$ $\quad E \rightarrow E / E$
  - $E \rightarrow (E)$ $\quad E \rightarrow$ **id**
- Use different non-terminals for each

  Precedence level: (start from lowest level)
  - $E \rightarrow E - E$ $\quad E \rightarrow T$
  - $T \rightarrow T / T$ $\quad T \rightarrow F$
  - $F \rightarrow$ **id** $\quad F \rightarrow (E)$
- Input: id - id / id

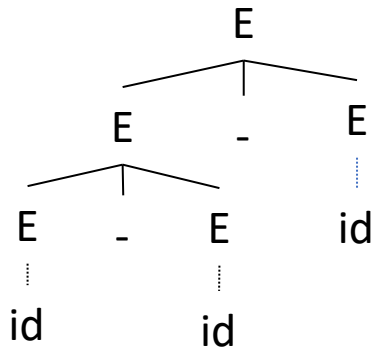


Q: Using this CFG write down two leftmost derivations for input string `id-id-id`

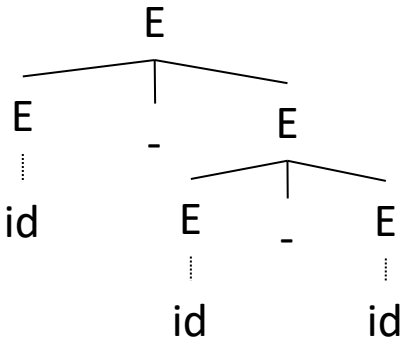
Associativity

- Grammar captures operator precedence
  - $E \rightarrow E - E$ $\quad E \rightarrow T$
  - $T \rightarrow T / T$ $\quad T \rightarrow F$
  - $F \rightarrow$ **id** $\quad F \rightarrow (E)$
- Still ambiguous!!
  - Consider: id - id – id
  - "-" is left associative
  - Operations are grouped from left to right

5-3-2



(5-3)-2



5-(3-2)

Recursion

- Grammar is recursive in nonterminal X if:
  - $X \Rightarrow^{+} \ldots X \ \ldots$
    - $\Rightarrow^{+}$ means in one or more steps, X derives a sequence of symbols that includes X
- Grammar is left recursive in X if:
  - $X \Rightarrow^{+} X \ \ldots$
    - In one or more steps, X derives a sequence of symbols that starts with X
- Grammar is right recursive in X if:
  - $X \Rightarrow^{+} \ldots X$
    - In one or more steps, X derives a sequence of symbols that ends with X

Fix Associativity

- Left and right recursive in non-terminals E and T
  - $E \rightarrow E - E$ $\quad E \rightarrow T$
  - $T \rightarrow T / T$ $\quad T \rightarrow F$
  - $F \rightarrow$ **id** $\quad F \rightarrow (E)$
- Express operator associativity:
  - For left associativity use left recursion
  - For right associativity use right recursion

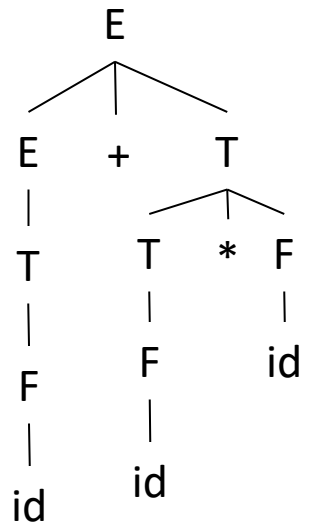
- Unambiguous grammar
  - $E \rightarrow E - T$ $\quad E \rightarrow T$
  - $T \rightarrow T / F$ $\quad T \rightarrow F$
  - $F \rightarrow$ **id** $\quad F \rightarrow (E)$

Q: Using this CFG write down all possible leftmost derivations for each input string below:

1. `id-id-id`
2. `id-id/id`
3. `(id-id)/id`

Precedence and Associativity

- Original ambiguous grammar:
  - $E \rightarrow E + E$ $\quad E \rightarrow E * E$
  - $E \rightarrow (E)$ $\quad E \rightarrow - E$
  - $E \rightarrow id$
- Unambiguous grammar:
  - $E \rightarrow E + T$ $\quad T \rightarrow T * F$
  - $E \rightarrow T$ $\quad T \rightarrow F$
  - $F \rightarrow (E)$ $\quad F \rightarrow - E$
  - $F \rightarrow id$
- Input: id + id * id



Warning! Is this unambiguous?
Check derivations for `-id+id`

Q: Compare with $F \rightarrow - F$

Dangling else ambiguity

- Original Grammar (ambiguous)

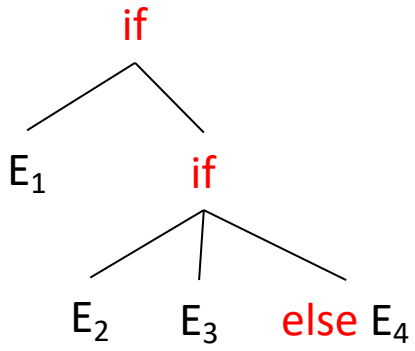
  Stmt → **if** Expr **then** Stmt **else** Stmt

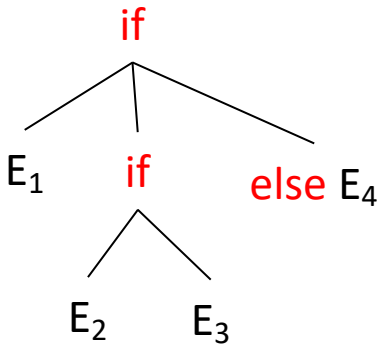
  Stmt → **if** Expr **then** Stmt

  Stmt → Other

- if E_1 then if E_2 then E_3 else E_4

  else matches the closest unmatched then





Dangling else ambiguity

- Original Grammar (ambiguous)

  Stmt → **if** Expr **then** Stmt **else** Stmt

  Stmt → **if** Expr **then** Stmt

  Stmt → Other

- Unambiguous grammar

  Stmt → MatchedStmt /*all then are matched*/

  Stmt → UnmatchedStmt /*some then are unmatched*/

  MatchedStmt → **if** Expr **then** MatchedStmt **else** MatchedStmt

  MatchedStmt → Other

  UnmatchedStmt → **if** Expr **then** Stmt

  UnmatchedStmt → **if** Expr **then** MatchedStmt **else** UnmatchedStmt

else matches the closest unmatched then

Dangling else ambiguity

- Check unambiguous dangling-else grammar with the following inputs:
  - if Expr then if Expr then Other else Other
  - if Expr then if Expr then Other else Other else Other
  - if Expr then if Expr then Other else if Expr then Other else Other

Precedence and Associativity Declaration

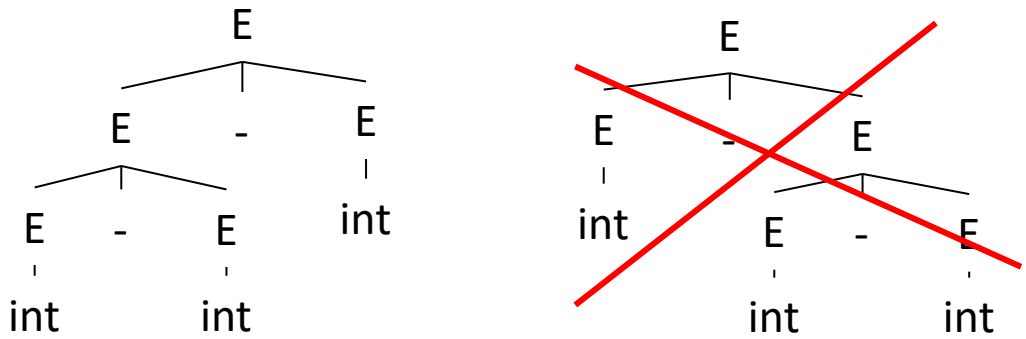
- Impossible to automatically convert an ambiguous grammar to an unambiguous one
- Used with care, potentially ambiguous grammars can be useful:
  - Allows a grammar that is easier to read for humans
  - However it needs disambiguation mechanisms like precedence & associativity

Precedence and Associativity Declaration

- Instead of re-writing the grammar
  - Use the more natural (ambiguous) grammar
  - Along with disambiguation declarations
- Most tools allow precedence and associativity declaration to disambiguate grammars

Associativity Declaration

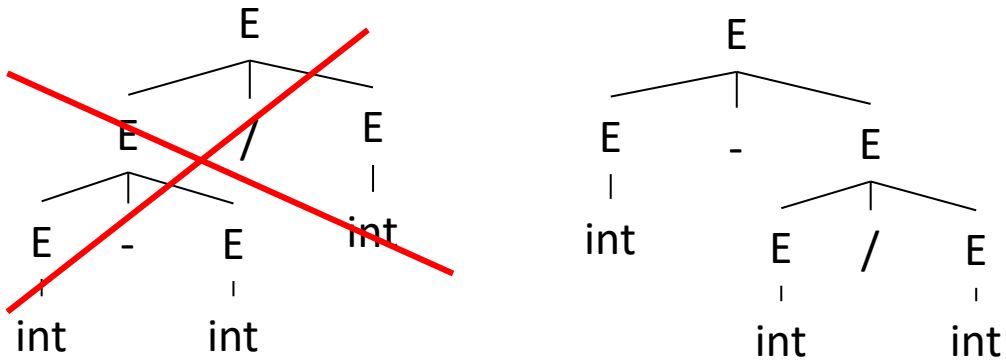
- Consider the grammar:
  - E → E - E | int
- Ambiguous: two parse trees int - int - int



- Left associativity declaration: %left -

Precedence Declaration

- Consider the grammar:
  - E → E - E | E / E | int
- Ambiguous: two parse trees int - int / int



- Precedence declaration: %left – lower priority
  %left / higher priority

Extra Slides

Other Ambiguous Grammars

- Consider the grammar

$$
\begin{aligned}
R \rightarrow\ & R\ \text{`|'}\ R \\
\mid\ & R\ R \\
\mid\ & R\ \text{`*'} \\
\mid\ & \text{`('}\ R\ \text{`)'} \\
\mid\ & a \\
\mid\ & b
\end{aligned}
$$

- What does this grammar generate?
- What is the parse tree for a|b*a
- Is this grammar ambiguous?

Dangling else ambiguity

- Original Grammar (ambiguous)

  Stmt → **if** Expr **then** Stmt **else** Stmt

  Stmt → **if** Expr **then** Stmt

  Stmt → Other

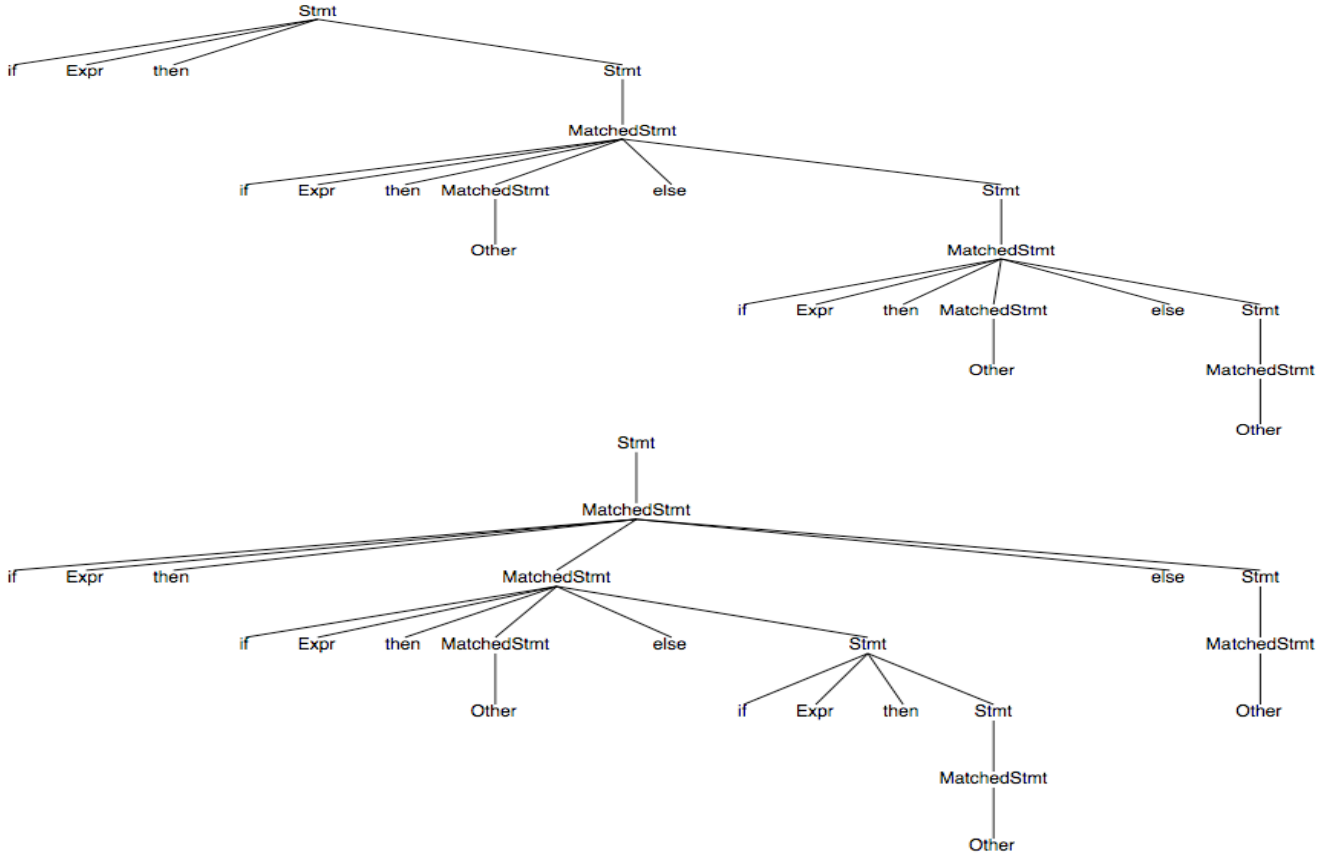
- Modified Grammar (unambiguous?)

  Stmt → **if** Expr **then** Stmt

  Stmt → MatchedStmt

  MatchedStmt → **if** Expr **then** MatchedStmt **else** Stmt

  MatchedStmt → Other


Stmt
if
Expr
then
Stmt
MatchedStmt
if
Expr
then
MatchedStmt
else
Stmt
Other
MatchedStmt
if
Expr
then
MatchedStmt
else
Stmt
Other
MatchedStmt
Other
Stmt
MatchedStmt
if
Expr
then
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Stmt
if
Expr
then
MatchedStmt
else
Stmt
Other
MatchedStmt
if
Expr
then
Stmt
Other
MatchedStmt
Other

Dangling else ambiguity

- Modified Grammar (check for ambiguity)

  Stmt → MatchedStmt

  Stmt → UnmatchedStmt

  MatchedStmt → **if** Expr **then** MatchedStmt **else** MatchedStmt

  MatchedStmt → Other

  UnmatchedStmt → **if** Expr **then** Stmt

  UnmatchedStmt → **if** Expr **then** MatchedStmt **else** UnmatchedStmt