CFG2: Ambiguity

Context-Free Grammars

CMPT 379: Compilers

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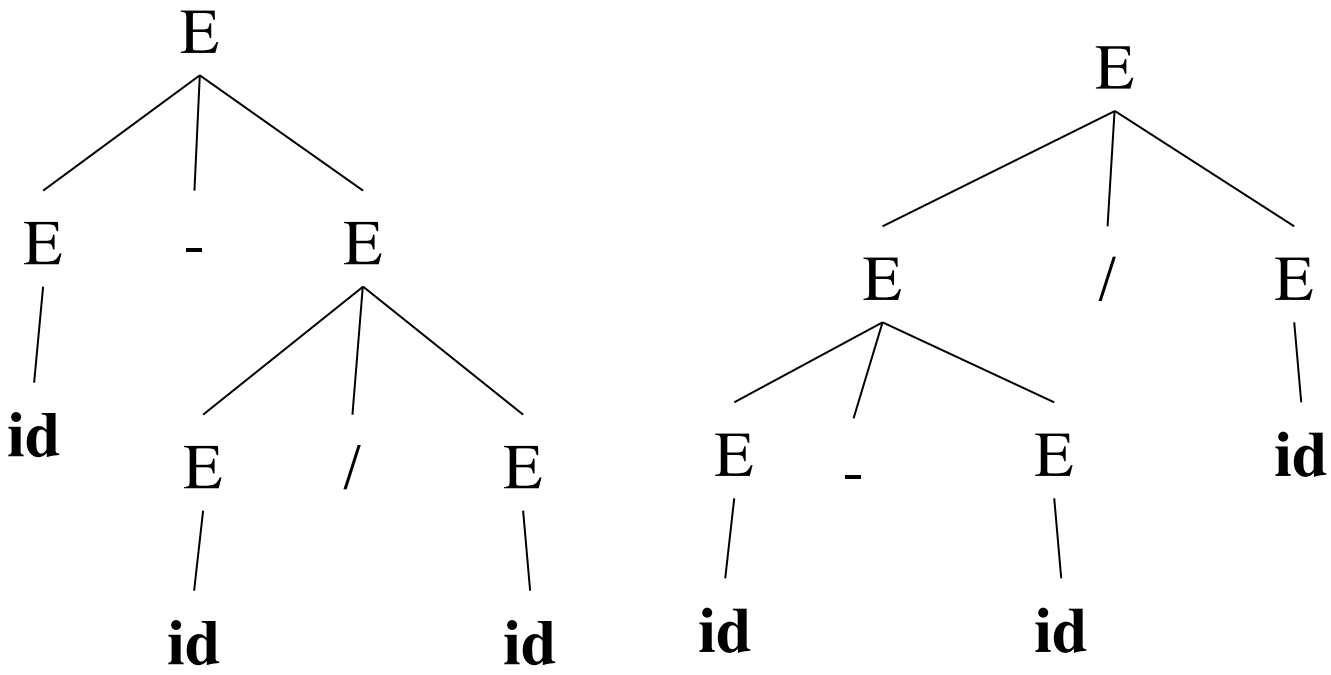
Ambiguity

E → E - E
E → E / E
E → (E)
E → **id**

id - id / 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

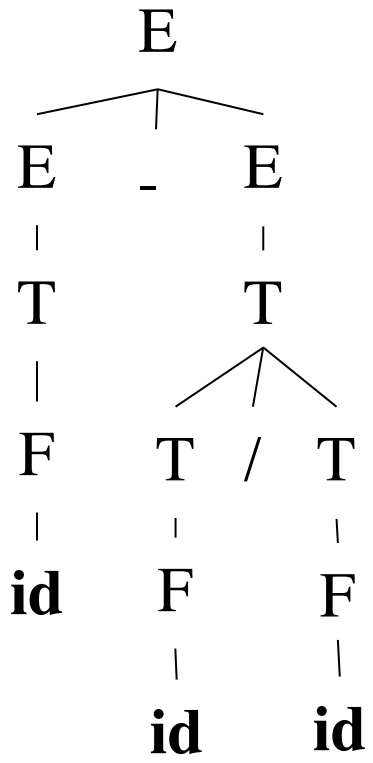
- Handle ambiguity:
  - Rewrite the grammar unambiguously
  - Augment parser by enforcing precedence and associativity
- Consider the original ambiguous grammar:

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

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

Precedence

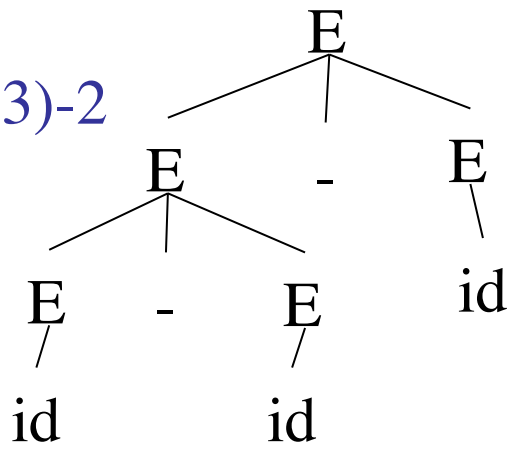
- Original ambiguous grammar:
  - E → E - E E → E / E
  - E → (E) E → **id**
- Use different non-terminals for each Precedence level: (start from lowest level)
  - E → E - E E → T
  - T → T / T T → F
  - F → **id** F → (E)
- Input: id - id / id



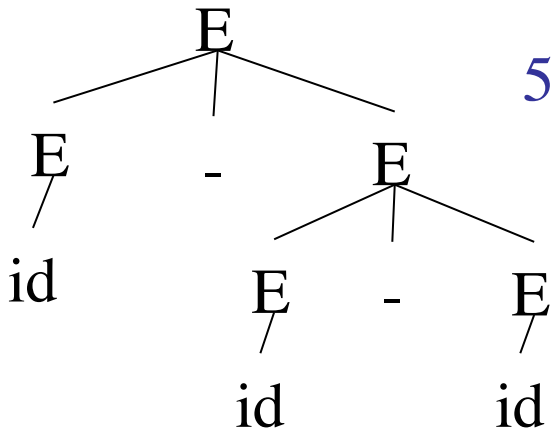
Associativity

- The grammar capture operator precedence
  - E → E - E E → T
  - T → T / T T → F
  - F → **id** F → (E)
- Still ambiguous!! id - id – id 5-3-2
  - "-" is left associative (operations are grouped from left)

(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
  - $E \rightarrow E - E$ $\quad E \rightarrow T$
  - $T \rightarrow T / T$ $\quad T \rightarrow F$
  - $F \rightarrow \mathbf{id}$ $\quad F \rightarrow (E)$
- Express operator associativity:
  - For left associativity use left recursion
  - For right associativity use right recursion
- Unambiguous grammar
  - $E \rightarrow E - T$ $\quad E \rightarrow T$
  - $T \rightarrow T / F$ $\quad T \rightarrow F$
  - $F \rightarrow \mathbf{id}$ $\quad F \rightarrow (E)$

Dangling else ambiguity

- Original Grammar (amibguous)

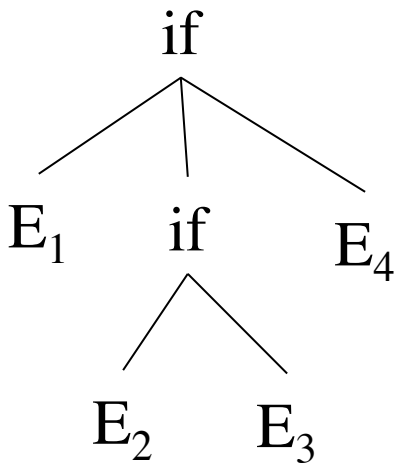
  Stmt → **if** Expr **then** Stmt **else** Stmt

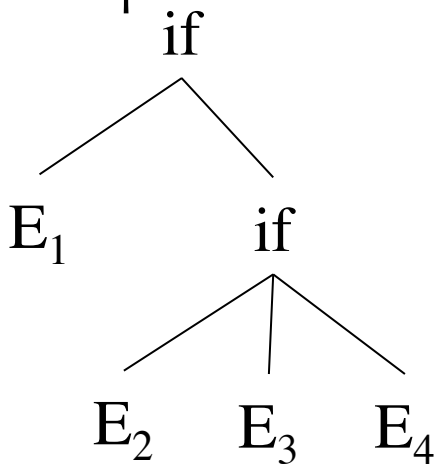
  Stmt → **if** Expr **then** Stmt

  Stmt → Other

else matches the closest unmatched then

- if E_1 then if E_2 then E_3 else E_4





Dangling else ambiguity

- Original Grammar (ambiguous)

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

  Stmt → **if** Expr **then** Stmt

  Stmt → Other

else matches the closest unmatched then

- 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

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

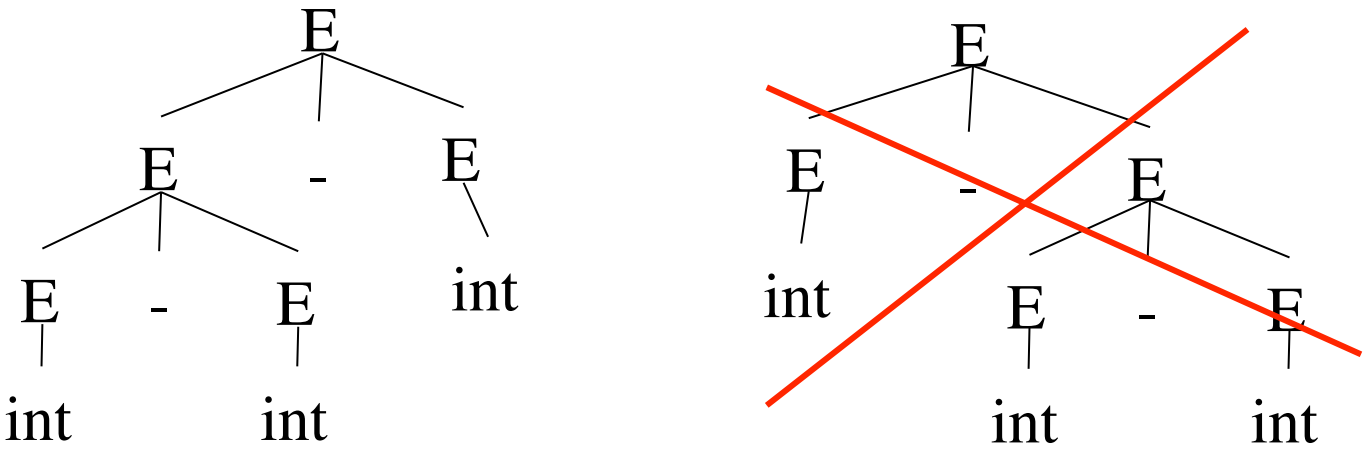
- Impossible to automatically convert an ambiguous grammar to an unambiguous one
- Used with care, ambiguity can simplify the grammar
  - Sometimes allow more natural definitions
  - We need disambiguation mechanisms

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

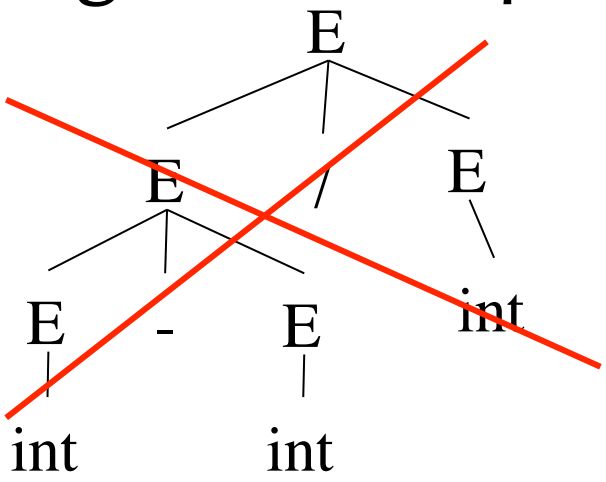
- Consider the grammar:
  - E → E - E | int
- Ambiguous: two parse trees int - int - int

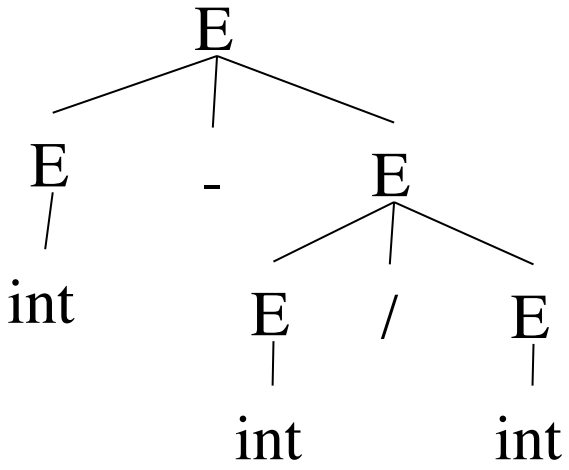


- Left associativity declaration: %left -

Precedence Declaration

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





- Precedence declaration: %left –

  %left /

Other Ambiguous Grammars

- Consider the grammar

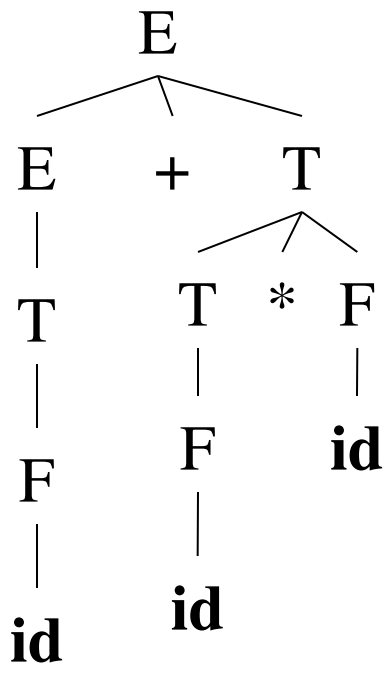
$$
\begin{aligned}
R \rightarrow\ & R\ \text{`|'}\ R \\
\mid\ & R\ R \\
\mid\ & R\ \text{`*'} \\
\mid\ & \text{`('}\ R\ \text{`)'} \\
\mid\ & a \\
\mid\ & b
\end{aligned}
$$

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

Extra Slides

Ambiguity

- 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

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

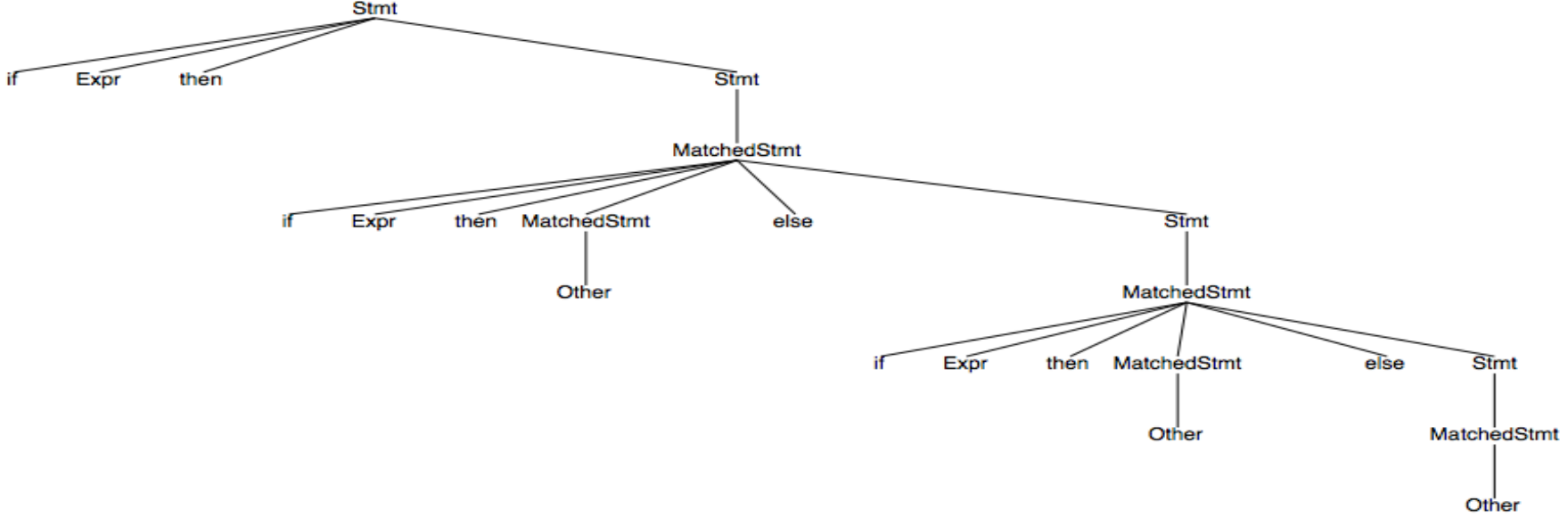
- Modified Grammar (unambiguous?)

  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
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Other
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then
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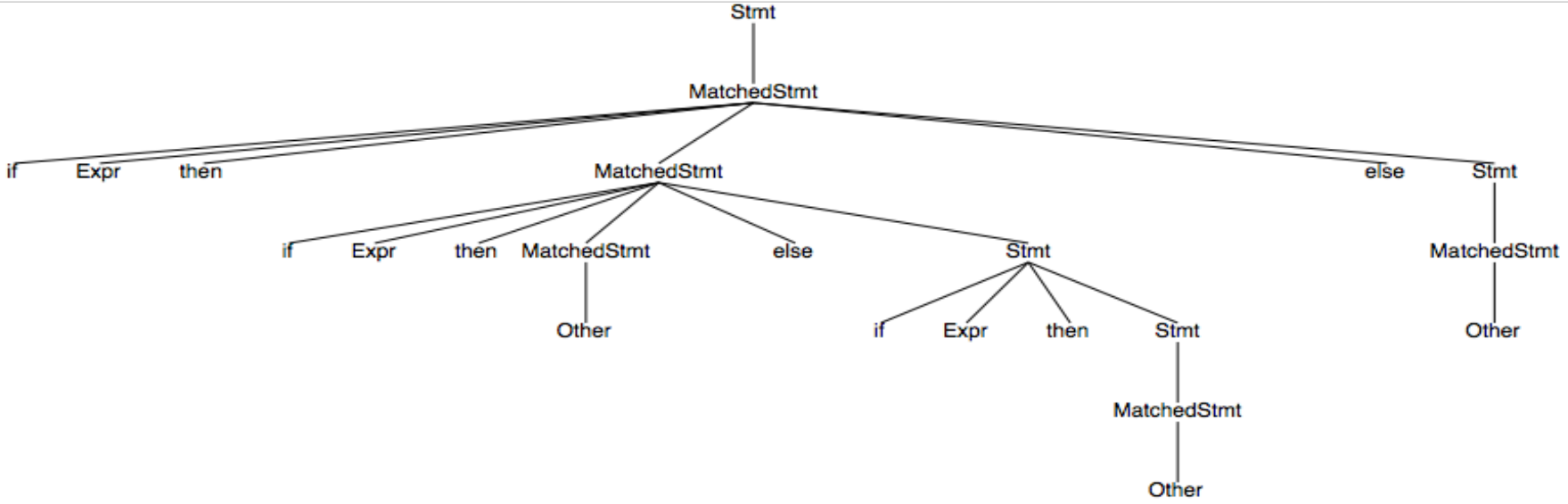
Other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