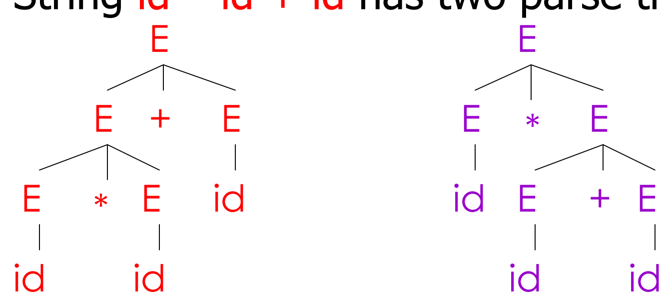
Ambiguity

- Defining
- Rewriting:
  - Expression Grammars
    - precedence
    - associativity
  - IF-THEN-ELSE
    - the Dangling-ELSE problem
- Declarations
  - Expression Grammars
    - precedence
    - Associativity
- Readings: Sections 4.2, 4.3

Ambiguity = program structure not uniquely defined

$E \rightarrow E+E \mid E*E \mid (E) \mid id$

String id * id + id has two parse trees:



Ambiguity

- A grammar is *ambiguous* if, for any string
  - it has more than one parse tree, or
  - there is more than one right-most derivation, or
  - there is more than one left-most derivation

  (the three conditions are equivalent)

- Ambiguity is **BAD**
  - Leaves meaning of some programs ill-defined

Dealing with Ambiguity

- There are several ways to handle ambiguity
- We will discuss two of them:
  - rewriting the grammar
  - parser-generator declarations

Expression Grammars (precedence)

- Rewrite the grammar
  - use a different nonterminal for each precedence level
  - start with the lowest precedence (MINUS)

E → E - E | E / E | (E) | id

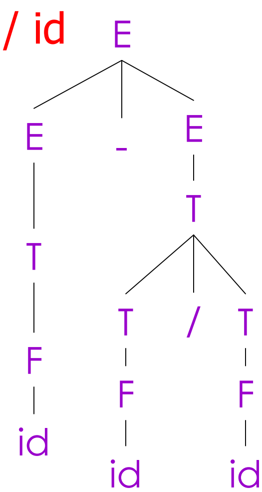
rewrite to

E → E - E | T
T → T / T | F
F → id | (E)

Example

parse tree for id – id / id

E → E - E | T
T → T / T | F
F → id | (E)



Example: Preventing Ambiguity

- **Question:** can we construct parse tree for id-id/id that shows the wrong precedence?

Associativity

- The grammar captures operator precedence, but it is still ambiguous!
  - fails to express that both subtraction and division are *left* associative;
    - e.g., 5-3-2 is equivalent to: ((5-3)-2) and *not* to: (5-(3-2))
- Example: two parse trees for the expression 5-3-2 using the grammar given above; one that correctly groups 5-3, and one that incorrectly groups 3-2

Recursion

- Grammar is recursive in nonterminal X if:
  - X $\rightarrow^+$ … X …
    - $\rightarrow^+$ means "in one or more steps, X derives a sequence of symbols that includes an X"
- Grammar is left recursive in X if:
  - X $\rightarrow^+$ X …
    - in one or more steps, X derives a sequence of symbols that *starts* with an X
- A grammar is right recursive in X if:
  - X $\rightarrow^+$ … X
    - in one or more steps, X derives a sequence of symbols that *ends* with an X

How to fix associativity

- The grammar given above is both left and right recursive in nonterminals exp and term
  - try this: write the derivation steps that show this
- To correctly expresses operator associativity:
  - For left associativity, use left recursion
  - For right associativity, use right recursion
- Here's the correct grammar:

  E → E – T | T

  T → T / F | F

  F → id | (E)

Ambiguity: The Dangling Else

- Consider the grammar

  E $\rightarrow$ if E then E
  | if E then E else E
  | print

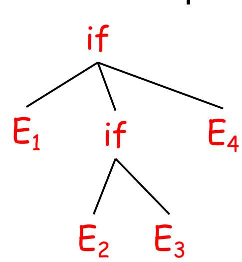
- This grammar is also ambiguous

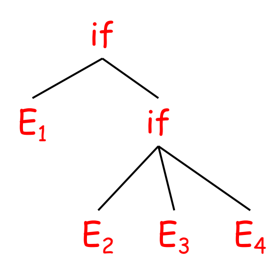
The Dangling Else: Example

- The expression

  if E_1 then if E_2 then E_3 else E_4

  has two parse trees





- Typically we want the second form

The Dangling Else: A Fix

- else matches the closest unmatched then
- We can describe this in the grammar

E → MIF /* all then are matched */
  | UIF /* some then are unmatched */

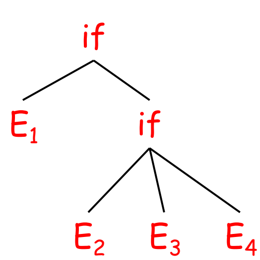
MIF → if E then MIF else MIF
  | print

UIF → if E then E
  | if E then MIF else UIF

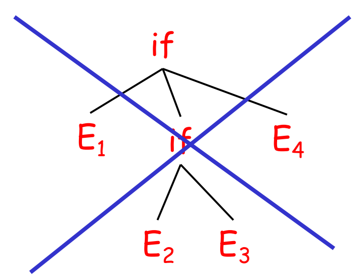
- Describes the same set of strings

The Dangling Else: Example Revisited

- The expression if E_1 then if E_2 then E_3 else E_4



- A valid parse tree (for a UIF)



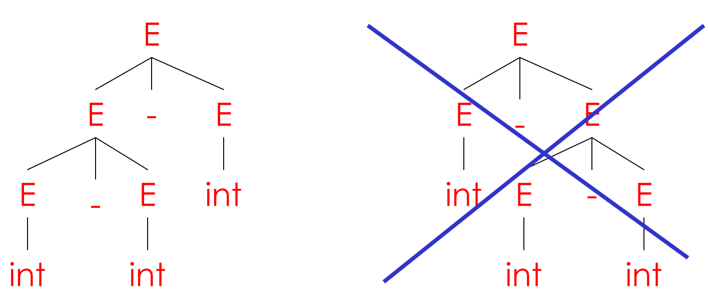
- Not valid because the then expression is not a MIF

Precedence and Associativity Declarations

- Instead of rewriting the grammar
  - Use the more natural (ambiguous) grammar
  - Along with disambiguating declarations
- Most parser generators allow precedence and associativity declarations to disambiguate grammars
- Examples …

Associativity Declarations

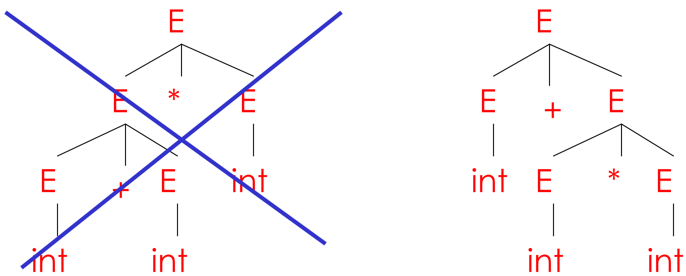
- Consider the grammar $E \rightarrow E - E \mid int$
- Ambiguous: two parse trees of int - int - int



- Left associativity declaration: %left +

Precedence Declarations

- Consider grammar E → E + E | E * E | int
  - And the string int + int * int



- Precedence declarations: %left +
  %left *