Programming Languages and Compilers (CS 421)

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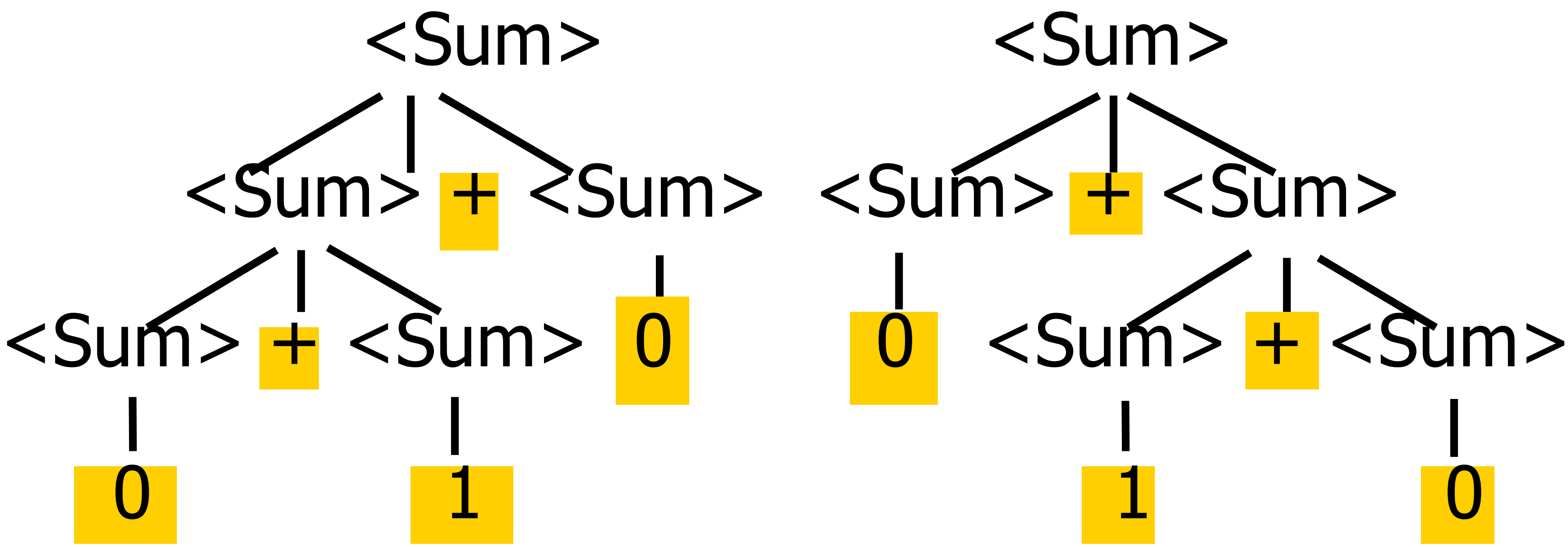
Based in part on slides by Mattox Beckman, as updated by Vikram Adve and Gul Agha

Ambiguous Grammars and Languages

- A BNF grammar is *ambiguous* if its language contains strings for which there is more than one parse tree
- If all BNF's for a language are ambiguous then the language is *inherently ambiguous*

Example: Ambiguous Grammar

- 0 + 1 + 0



Example

- What is the result for:

$$3 + 4 * 5 + 6$$

Example

- What is the result for:

  3 + 4 * 5 + 6

- Possible answers:
  - 41 = ((3 + 4) * 5) + 6
  - 47 = 3 + (4 * (5 + 6))
  - 29 = (3 + (4 * 5)) + 6 = 3 + ((4 * 5) + 6)
  - 77 = (3 + 4) * (5 + 6)

Example

- What is the value of:

$$7 - 5 - 2$$

Example

- What is the value of:

$$7 - 5 - 2$$

- Possible answers:
  - In Pascal, C++, SML assoc. left

    $7 - 5 - 2 = (7 - 5) - 2 = 0$
  - In APL, associate to right

    $7 - 5 - 2 = 7 - (5 - 2) = 4$

Two Major Sources of Ambiguity

- Lack of determination of operator precedence
- Lack of determination of operator associativity

- Not the only sources of ambiguity

Example

- Ambiguous grammar:

  <exp> ::= 0 | 1 | (<exp>)
  | <exp> + <exp>
  | <exp> * <exp>

- Strings with more then one parse:

  0 + 1 + 0

  1 * 1 + 1

- Sources of ambiguity here: associativity and precedence

Operator Precedence

- Operators of highest precedence get arguments first (bind more tightly).
  - This generally means evaluated first
- Precedence for infix binary operators given in following table
- Needs to be reflected in grammar

Precedence Table - Sample

	Fortan	Pascal	C/C++	Ada	SML
highest	**	*, /, div, mod	++, --	**	div, mod, /, *
	*, /	+, -	*, /, %	*, /, mod	+, -, ^
	+, -		+, -	+, -	::

Disambiguating a Grammar

- Given ambiguous grammar G, with start symbol S, find a grammar G′ with same start symbol, such that

  language of G = language of G′

- Not always possible
- No algorithm in general

Disambiguating a Grammar

- Idea: Each non-terminal represents all strings having some property, its language
  - Each rule describes a sublanguage
- Identify these properties (often in terms of things that can't happen)
- Use these properties to inductively guarantee every string in language has a unique parse

Steps to Grammar Disambiguation

- Identify the rules and a smallest use that display ambiguity
- Decide which parse to keep; why should others be thrown out?
- What syntactic restrictions on subexpressions are needed to throw out the bad (while keeping the good)?
- Add a new non-terminal and rules to describe this set of restricted subexpressions (called stratifying, or refactoring)
- **Characterize each non-terminal by a language invariant**
- Replace old rules to use new non-terminals
- Rinse and repeat

How to Enforce Associativity

- Have at most one recursive call per production

- When two or more recursive calls would be natural, leave right-most one for right associativity, left-most one for left associativity

Example

- <Sum> ::= 0 | 1 | <Sum> + <Sum>
  | (<Sum>)
- Becomes
  - <Sum> ::= <Num> | <Num> + <Sum>
  - <Num> ::= 0 | 1 | (<Sum>)

<Sum> + <Sum> + <Sum>

Predence in Grammar

- Higher precedence translates to longer derivation chain
- Example: * higher than +, both assoc left

<exp> ::= 0 | 1 | (exp>)
        | <exp> + <exp> | <exp> * <exp>

- Becomes

  <exp> ::= <mult_exp>
          | <exp> + <mult_exp>
  <mult_exp> ::= <id> | <mult_exp> * <id>
  <id> ::= 0 | 1 | (<exp>)

Many other sources

- Many other sources
- Can apply same general approach
- Need insights into cause
- Need insights into restrictions to solve
- No general algorithm
- Process:
  - Stratify
  - Prove sublanguages disjoint
  - Prove union of new sublanguages give old language
- Method: Invariants and Induction