More on BNFs

COMP360

“Metaphors, similes, puns - all manner of metonymy - I'm interested in language that cannot be parsed by a machine - language that can only be understood through acculturation.”

Joshua Cohen

Homework

- An assignment has been posted on Blackboard
- You have to write:
  - four regular expressions
  - DFAs to implement two of the regular expressions
  - a program to implement one of the DFA
- Due by noon on Monday, March 14, 2016, after spring break

Syntactical Analysis

- The Syntactical Analysis stage or Parsing stage of a compiler accepts the list of tokens created by lexical scanner and creates a parse tree for use by the semantic analyzer
- This portion of a compiler detects most of the syntax errors
- We assume that our language can be defined as a context free language

Backus-Naur Form

- Context Free Grammars can be defined using the Backus-Naur Form or **BNF**
- Created by John Backus and Peter Naur. Independently created by Noam Chomsky
- BNF is a **metalanguage**, a language used to describe a language

BNF Fundamentals

- Terminal symbols are tokens or symbols in the language. They come from the lexical scanner
- Nonterminal symbols are “variables” that represent patterns of terminals and nonterminal symbols
- A BNF consists of a set of **productions** or **rules**
- A language description is called a **grammar**

BNF Structure

- Nonterminal symbols are sometimes enclosed in brackets to differentiate them from terminal symbols
- I will use **bold font** for terminal symbols and no brackets
- Productions are of the form:

  nonterminal → nonterminals or terminals

- Multiple definitions are separated by | meaning OR

  whatever → this | that

BNF to Define a Language

- There must be one nonterminal start symbol which must appear at least once on the left hand side of a rule
- The start symbol defines the language and all other rules follow from it

BNF Example

wloop → **while (** logical **)** stmt

logical → exp relation exp

relation → > | < | **==** | **!=**

stmt → *something not defined here*

exp → *something not defined here*

Recursive Lists

- BNF rules can be recursive generating arbitrarily long statements

stuff → thing | thing , stuff

- Following this rule, stuff can be:

thing *or* thing, thing *or* thing, thing, thing, thing, thing

Try It

- Write a BNF to describe a language that allows

:f(name)

:s(name)

:(name)

:f(name)s(name)

:s(name)f(name)

Possible Solution

choice → **:** always | **:** good | **:** fail | **:** good fail | **:** fail good

always → (name)

good → s(name)

fail → f(name)

Recognizers and Generators

- A BNF can be used to generate an example of the language
- A string is in a language if and only if it can be generated by the language
- There are programming techniques that can determine if a string is a correct example of a language

BNF for Assignment Statement

1. assign → var **=** exp
2. var → **X** | **Y** | **Z**
3. exp → var **+** exp
4. | var ***** exp
5. | **(** exp **)**
6. | var

Derivations

- A derivation is an example of the language created by successively applying rules
- Derivations always begin with the start nonterminal symbol

Deriving X = Z * (X + Y)

1	var = exp
2	**X** = exp
4	**X** = var * exp
2	**X** = **Z** * exp
5	**X** = **Z** * **(** exp **)**
3	**X** = **Z** * **(** var **+** exp **)**
2	**X** = **Z** * **(** **X** **+** exp **)**
6	**X** = **Z** * **(** **X** **+** var **)**
2	**X** = **Z** * **(** **X** **+** **Y** **)**

1. assign → var **=** exp
2. var → **X** | **Y** | **Z**
3. exp → var **+** exp
4. | var * exp
5. | **(** exp **)**
6. | var

Write a derivation

- Show a derivation for Z = Y + X * Z

1. assign → var **=** exp
2. var → **X** | **Y** | **Z**
3. exp → var **+** exp
4. | var * exp
5. | **(** exp **)**
6. | var

Possible Solution

- Show a derivation for Z = Y + X * Z

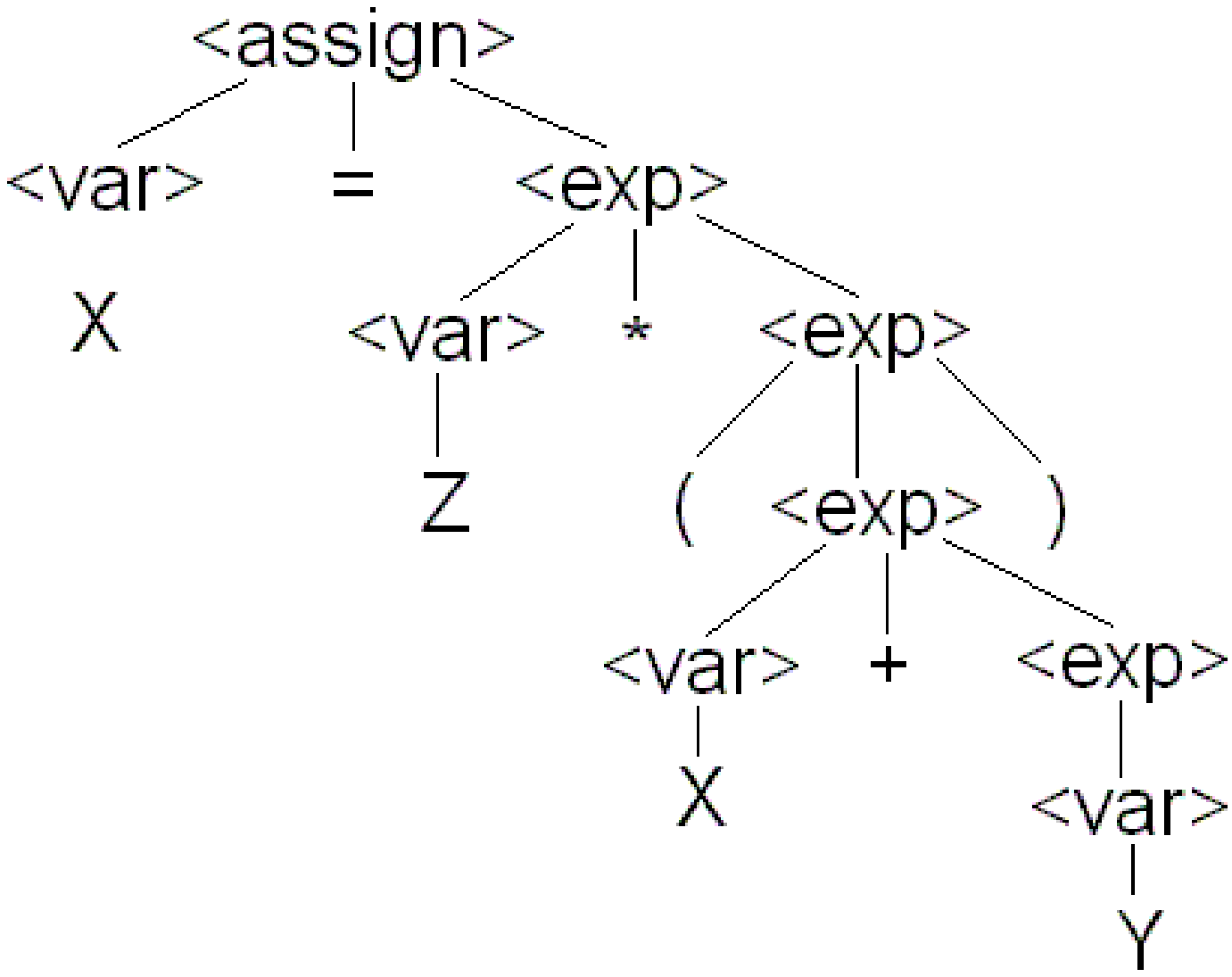
1	var = exp
2	Z = exp
3	Z = var + exp
2	Z = Y + exp
4	Z = Y + var * exp
2	Z = Y + X * exp
6	Z = Y + X * var
2	Z = Y + X * Z

1. assign → var **=** exp
2. var → **X** | **Y** | **Z**
3. exp → var **+** exp
4. | var * exp
5. | **(** exp **)**
6. | var

Parse Tree

- A parse tree graphically shows a derivation
- Each nonterminal in the tree has branches representing the symbols on the right side of a rule defining that nonterminal
- All of the leaves of a parse tree are terminal symbols

Derivation Tree



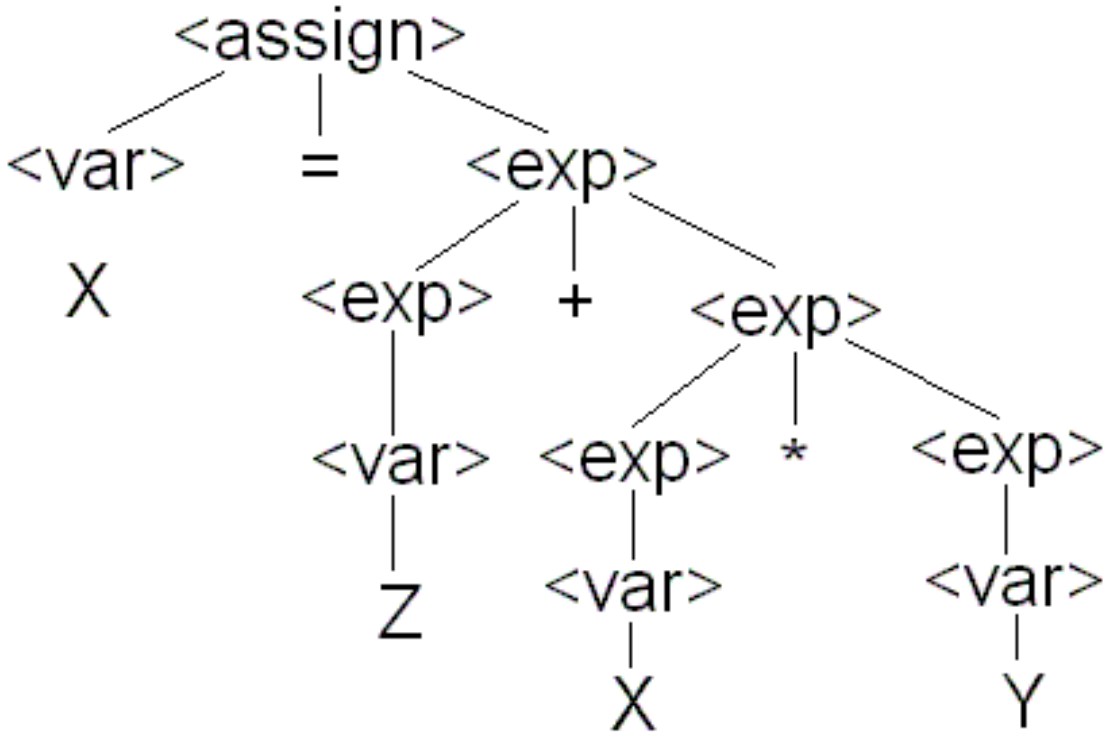
Ambiguous Grammars

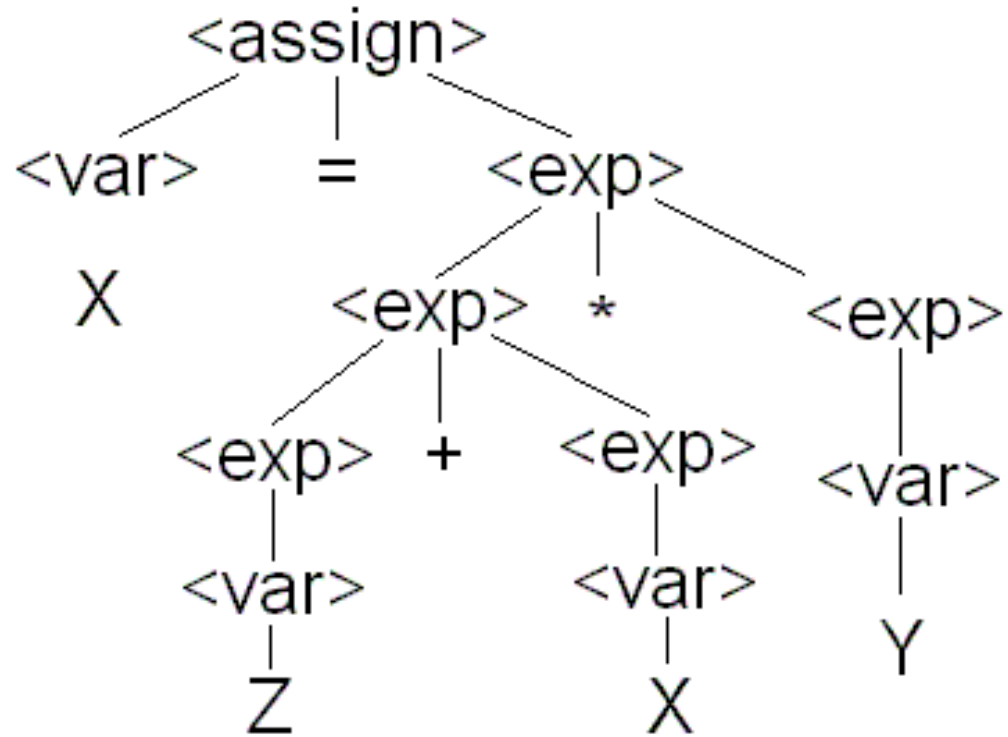
- For each string in a language, there must be one and only one derivation or parse tree that creates that string
- A grammar is ambiguous if the same member of the language can be created by two or more different derivations

Ambiguous Expression Grammar

1. assign → var **=** exp
2. var → **X** | **Y** | **Z**
3. exp → exp **+** exp
4. | exp * exp
5. | **(** exp **)**
6. | var

Different Trees





Unambiguous Expression Grammar

1. assign → var **=** exp
2. var → **X** | **Y** | **Z**
3. exp → exp **+** term
4. | term
5. term → term * factor
6. | factor
7. factor → **(** exp **)**
8. | var

Precedence

- Note that this unambiguous grammar also provides priority for multiplication over division
- An expression (exp) will be recognized before a term
- The terms group multiplications which are then grouped for addition

The Sad Truth

- Study of computer science theory has proven that certain problems cannot be solved
- It is not possible to write a program that will read in a grammar and determine that it is not ambiguous

Grammar Problems

- Ambiguous Grammars
  - There exists more than one interpretation of what the input means
- Grammars that are not unique within a limited context
- Ambiguous Languages
  - There exist context-free languages that do not have an unambiguous grammar

Unique Productions

- Parsers only look a few characters ahead, usually one character
- It is difficult to parse a language if different rules in the grammar have identical right hand sides

$$A \rightarrow B\ C\ D$$

$$X \rightarrow B\ C\ D$$

Limited Context

- It is difficult to parse a language if the first several symbols of a right hand side are similar to another rule

$$A \rightarrow B\ C\ D\ E\ X$$
$$\mid B\ C\ D\ E\ Y$$

Parsing Complexity

- Parsing algorithms that work for any unambiguous grammar are complex and slow
- General parsing algorithms are $O(n^3)$
- Algorithms for grammars described in particular formats can be O(n)

Chomsky Normal Form

- All productions of a Chomsky Normal Form BNF are in the format:

  $A \rightarrow B\ C$

  $A \rightarrow \mathbf{x}$

- All rules have a right side with two non-terminals or one terminal symbol
- All non-ambiguous grammars can be converted to Chomsky Normal Form

Greibach Normal Form

- All productions of a Greibach Normal Form BNF are in the format:

  A → **x**

  A → **x** B

  A → **x** B more terminals and nonterminals

- All rules have a right side starting with one terminal symbol then possibly a non-terminal and maybe more symbols
- All non-ambiguous grammars can be converted to Greibach Normal Form (GNF)

Simple Grammar in GNF

1. assign → **var** = exp
2. exp → **var** + exp
3. | **var** * exp
4. | **(** exp **)**
5. | **var**

Write a BNF

- A Snobol assignment statement can be

```
var = var
var pattern = var
```

where pattern can be

```
var
var var var var …
var (var var) var …
```

Possible Solution

asg → **var = var** | **var** pattern **= var**

pattern → **var** | **var** pattern | **(** pattern**)**

Possible Solution in GNF

asg → **var** rside | **var** pattern rside

pattern → **var** | **var** pattern | **(** pattern**)**

rside → **= var**

General Parsing Rules

- The lexical scanner is simpler than the parser. Scan all you can
- Avoid long productions
- Chomsky and Greibach Normal Forms are useful, although not necessary

Looking for Ideas

- An upcoming assignment will ask you to write a scanner and a parser for a language
- We need a simple language to implement
- It must:
  - Not be trivial or too difficult
  - Not be a subset of Java arithmetic
  - Have more than one possible program

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