Computación y Estructuras Discretas III

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Languages

To define a languages we should define its lexical, syntactic and semantic components.

- The lexical, what?
- The syntactic, how?
- The semantic, what does it mean?

Agenda del día

1. **The process to design and implement a programming language**
   - EBNF
   - EBNF Rules and Descriptions
   - Language and Syntax
   - EBNF Rules and Descriptions
   - Proving Symbols Match EBNF Rules
   - Syntax versus Semantics
   - Exercises

Syntax and parsing

The syntax of programming languages, or at least a large portion of it, is typically presented using CFGs. In those cases, the language is said to be in Backus-Naur Form (BNF) or its extended version (EBNF).

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Languages described in BNF offer significant advantages for the design of syntactic analyzers in compilers.

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EBNF Rules and Descriptions

What is an EBNF description?

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- Is an unordered list of EBNF rules.
- Each EBNF rule has three parts:
  - A left-hand side (LHS),
  - A right-hand side (RHS),
  - The $\Leftarrow$ character separating these two sides.
- The LHS is one italicized word (possibly with underscores) written in lower-case.
  - It names the EBNF rule.
- The RHS supplies a description of this name.
  - It can include names, characters (standing for themselves), and combinations of the four control forms (sequence, choice, option repetition).

What is EBNF?

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- **MetaLanguage**
- Notation for formally describing syntax (how to write the linguistic features in a language).
- Also similar is the ability to name descriptions and reuse these names to build more complex structures.

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Language and Syntax

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And who was involved in both initiatives?

- John Backus
- He led the effort to develop FORTRAN.
- Later became a member of the ALGOL design committee, where he studied the problem of describing the syntax of these programming languages simply and precisely.

Language and Syntax

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Language and Syntax

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- He invented a notation (based on the work of logician Emil Post) that was simple, precise, and powerful enough to describe the syntax of any programming language.
- Using this notation, a programmer or compiler can determine whether a program is syntactically correct: whether it adheres to the grammar and punctuation rules of the programming language.

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And who popularized this notation?

- Peter Naur
- As an editor of the ALGOL report, he popularized this notation by using it to describe the complete syntax of ALGOL.
- In Backus and Naur's honor this notation is called Backus-Naur Form (BNF).

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- The linguist Noam Chomsky began working on a harder problem: describing the syntactic structure of natural languages.
- He developed four different notations that describe languages of increasing complexity.
    - Type 0 (unrestricted),
    - Type 1 (context-sensitive),
    - Type 2 (context-free),
    - Type 3 (regular).
- The power of Chomsky's type 2 notation is equivalent to EBNF.

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EBNF Rules and Descriptions

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EBNF Rules and Descriptions

Which are the four control forms of RHS?

- Sequence
  - Items appear left-to-right.
  - Their order is important.
- Choice
  - Alternative items are separated by a | (stroke).
  - One item is chosen from this list of alternatives.
  - Their order is unimportant.
- Option
  - The optional item is enclosed between [and] (square-brackets).
  - The item can be either included or discarded.
- Repetition
  - The repeatable item is enclosed between { and } (curly-braces).
  - The item can be repeated zero or more times.

EBNF Rules and Descriptions

Example

EBNF Description: *integer*

digit $\Leftarrow$ *0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9*
integer $\Leftarrow$ *[+ | -] digit{digit}*

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How to prove that a symbol is legal according to some EBNF rule?

- We must match all its characters with all the items in the EBNF rule, according to that rule's description.
- If there is an exact match we classify the symbol as legal according to that EBNF description and say it matches.
- Otherwise we classify the symbol as illegal and say it doesn't match.

Proving Symbols Match EBNF Rules

Example

EBNF Description: *integer*

digit	$\Leftarrow$ *0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9*
integer	$\Leftarrow$ *[+ | -] digit{digit}*

- *We can prove that the symbol +142 matches the integer EBNF rule.*
- *We can easily prove that 1,024 is an illegal integer.*

Proving Symbols Match EBNF Rules

What is a tabular proof?

Proving Symbols Match EBNF Rules

What is a tabular proof?

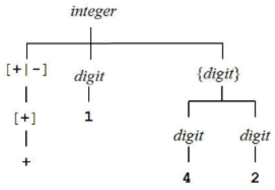
- A tabular proof is a more formal demonstration that a symbol matches an EBNF description.
- The first line in a tabular proof is always the name of the EBNF rule that specifies the syntactic structure we are trying to match the symbol against.
- The last line is the symbol we are matching.
- Each line is derived from the previous according to one of the following rules:
  1. Replace a name (LHS) by its definition (RHS)
  2. Choose an alternative
  3. Determine whether to include or discard an option
  4. Determine the number of times to repeat
- Combining rules 1 and 2 (1&2) simplifies our proofs by allowing us, in a single step, to replace a left-hand side by one of the alternatives in its right-hand side.

Proving Symbols Match EBNF Rules

Example

A tabular proof and its derivation tree that shows the symbol +142 matches the integer EBNF rule.

Status	Reason (rule #)
integer	Given
[+|−]*digit*{*digit*}	Replace *integer* by it RHS (1)
[+]*digit*{*digit*}	Choose + alternative (2)
+*digit*{*digit*}	Include option (3)
+1{*digit*}	Replace the first *digit* by 1 alternative (1&2)
+1*digit digit*	Use two repetitions (rule 4)
+14*digit*	Replace the first *digit* by 4 alternative (1&2)
+142	Replace the first *digit* by 2 alternative (1&2)



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Syntax versus Semantics

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- EBNF descriptions specify only syntax: the form in which something is written.
- They do not specify semantics: the meaning of what is written.
- Syntax = Form
- Semantics = Meaning
- Two semantic issues are important in programming languages:
  - Can different symbols have the same meaning?
  - Can one symbol have different meanings?
- Different symbols can have the same meaning and one symbol can have different meanings depending on its context

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