# Handbook of ¬<><∪∪ in English

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## Overall Structure

A input for the ¬<><∪∪ compiler compiler is converted into a sequence of tokens by the process same as Java (JLS 3.2), but the noterminal symbols of ¬<><∪∪ are defined by the following table.

| Noterminal | Description |
|---|---|
| *IDENTIFIER* | not starting with `$` |
| keywords | starting with `$` |
| separators/operators | the strings used in the following EBNF, `\|\|`, `&&`, `--`, `!!`, `**`, `++`, and `??` |
| *CHAR* | Java character literal |
| *STRING* | Java string literal |

This text draw the grammar of the input for the ¬<><∪∪ by EBNF with the following notation.

| Meta-notation | Description |
|---|---|
| *Italic* or *italic* | nonterminals |
| *ITALIC* | terminals (symbol) |
| `Underlined` | terminals (literal) |
| *expr1* \| *expr2* | alternative |
| $expr^*$ | Kleene star |
| $expr_{opt}$ | optional |

The sequence of tokens should be structured by the following grammar. The goal symbol is *Root*.

*Root* ::= *ParserDeclaration*
*ConstructorScope*$_{opt}$
*definition*$^*$

*ParserDeclaration* ::= `$protected`$_{opt}$ `$parser` *JavaName* `;`

*JavaName* ::= *IDENTIFIER* ( `.` *IDENTIFIER* )$^*$

*ConstructorScope* ::= `$protected` `$constructor` `;`

*definition* ::= *SubtokenDefinition*
| *TokenDefinition*
| *AliasDefinition*
| *TypeDefinition*

¬<><∪∪ outputs a single Java source file and it defines a top level class that contains many nested types. The name of the top level class is given by the *PackageDeclaration*. If it is described as `$protected`, the generated class has the default scope. Otherwise, it is public. The *ConstructorScope* makes the scope of the constructor of the generated top level class the default scope (not the protected scope). The *definition*s gives the details of the generated top level class.

## Lexical Analyzer

*SubtokenDefinition* ::=
`$subtoken` *IDENTIFIER* `=` *tokenExpression* `;`

*TokenDefinition* ::=
`$white`$_{opt}$ `$token`
*IDENTIFIER* ( `=` *tokenExpression*)$_{opt}$ `;`

The generated top level class contains a interface and a default implementaion for lexical analysis. The default implementation repeats cutting out, from the character sequence inputed into the implementaion, a **token** (or **an instance of a terminal**), which is a longest-**mached** string by a **terminal**.

A *TokenDefinition* defines a **terminal**. A terminal matches the character sequences that **matches** the *tokenExpression*, or matches no sequence if *tokenExpression* is omitted (used only for user-defined lexical analyzers). A *STRING* in *expression*s of non-`$abstract` *TypeDefinition*s and *AliasDefinition*s also defines a terminal. It matches the represented string.

If a terminal is `$white`, the instance of it is a **white token**. White tokens are ignored for parsing and useful for white spaces and comments.

A *SubtokenDefinition* gives a name the *tokenExpression* to be used in *tokenExpression*s.

*tokenExpression* is defined by the following table.

| Priority | *tokenExpression* | **Matched** Strings |
|---|---|---|
| 6 | *expr1* \| *expr2* | alternative one matches |
| 5 | *expr1* `&` *expr2* | both matches |
| | *expr1* `-` *expr2* | former matches, latter not |
| 4 | *expr1 expr2 ...* | connection of matches |
| 3 | `!` *expr* | not match |
| 2 | *expr* `*` | zero or more repeats |
| | *expr* `+` | one or more repeats |
| | *expr* `?` | one or zero repeats |
| 1 | `[` *expr* `]` | one or zero repeats |
| | `(` *expr* `)` | *expr* matches |
| | *CHAR* | the character |
| | *CHAR* `..` *CHAR* | a character between |
| | *STRING* | the string |
| | *IDENTIFIER* | (sub)terminal maches |

## Syntax Analyzer

*AliasDefinition* ::= *IDENTIFIER* `=` *expression* `;`

*TypeDefinition* ::= *modifiers IDENTIFIER supertypes*$_{opt}$
`{` *expression* `}`

*modifiers* ::= ( `$protected` | `$private` )$_{opt}$ `$abstract`$_{opt}$
| `$parsable`
| `$protected-parsable` `$protected`$_{opt}$

*supertypes* ::= `->` *TypeName* ( `&` *TypeName* )$^*$

*TypeName* ::= *IDENTIFIER*

*InlineExpression* ::= *TypeDefinition*

The generated top level class contains zero or more syntax analyzers, which parses the sequence of the tokens given by a lexical analyzer. The grammar is described by an extended EBNF. A *TypeDefinition* or an *AliasDefinition* describes a production. The *IDENTIFIER* describes the name of the defined **nonterminal**, and the *expression* gives the right-hand side of the production.

*TypeDefinition*s also appear in *expression*s as *InlineExpression*s for convenience.

The *expression* is defined by the following table.

| P. | *expression* | Matched Token Sequence |
|---|---|---|
| 5 | *expr1* `\|` *expr2* | alternative one matches |
| 4 | *expr1 expr2 ...* | connection of matches |
| 3 | *expr* `*` | zero or more repeats |
| | *expr* `+` | one or more repeats |
| | *expr* `?` | one or zero repeats |
| | *expr* `/` *TypeName* | *expr* matches (used to control types of labels) |
| 2 | *IDENTIFIER* `:` *expr* | *expr* matches (labeled expression) |
| | `$label` `:` *expr* | *expr* matches (labeled expression) |
| 1 | `[` *expr* `]` | one or zero repeats |
| | `(` *expr* `)` | *expr* matches |
| | `$embed` `(` *expr* `)` | *expr* matches (replaces aliases by its *expression*) |
| | *IDENTIFIER* | terminal or nonterminal matches |
| | *STRING* | the terminal |
| | *InlineExpression* | the nonterminal matches |

The syntax analyzer builds a **concrete syntax tree** (**CST**) first (See Example). A token (an instance of a terminal) is a leaf of the tree and **an instance of a nonterminal** is a node of the tree. The nodes has **labeled** children. A **labeled expression** formed as *label*`:`*expression* means the

instances of the terminals and noterminals in the *expression* are labeled by the *label*. An instance can be labeled by multiple labels and a label can label multiple instances. The same label can also appear twice or more in an *expression* lexically.

And then, the analyzer builds an **abstract syntax tree** (**AST**) by removing some nodes from the CST. All the node that is an instance of the nonterminal defined by *AliasDefinition* (**Alias**) is removed. The children of a removed node become the children of the parent node of the removed node. If there is the child that is labeled by `$label`, the analyzer replaces the `$label` with the labels that label the removed node. If no children labeled by `$label`, all the children become labeled by the labels the removed node has.

The analyzer outputs the objects representing the AST. A token is represented by an instance of the nested interface `Token`. A node is represented by an instance of the nested interface whose name is the same as the nonterminal an instance of which in the CST the node was. The nested interface has the method whose name is the same as a label, that has no arguments, and that returns the children labeled by the label. If the label labels at most one child, the static type of the result is **the most specific common type** of the children the label may label. If the label may label more than one children, the result is an array or `java.util.List` of the most specific common type.

The *supertypes* specifies the supertype(s) of the nested interface. A *TypeName* should be a name of the nonterminal defined by *TypeDefinition*. If no *supertypes* are specified, the nested interface is a subtype of the nested interface `Node`. `Token` is also a subtype of `Node`.

If a nonterminal is defined as `$parsable`, the generated top level class has public methods with various arguments to parse the grammer whose goal symbol is the nonterminal. If a nonterminal is defined as `$protected-parsable`, the generated top level class has similar methods but they are protected.

If a nonterminal is defined as `$protected` or `$private`, the nested interface whose name is the same as the nontermina is protected or private. Otherwise, it is public.

If a nonterminal is defined as `$abstract`, the nonterminal generates a nested interface but should not appear in non-`$abstract` *expression*s.

Example

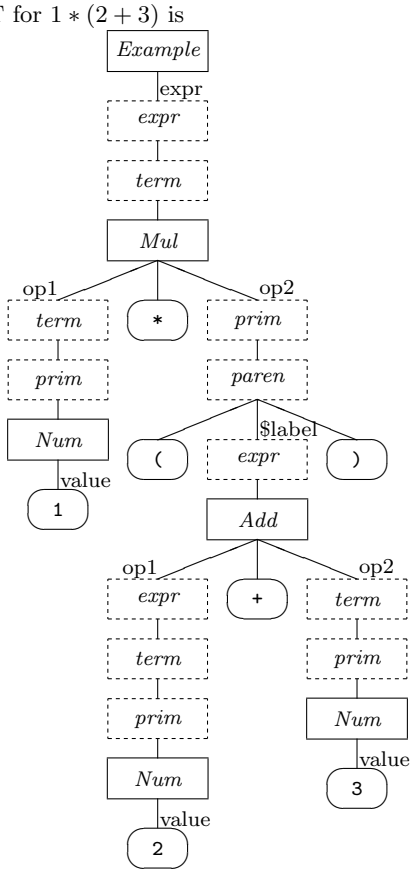
```
$parser parser.Parser;
$protected $constructor;

$token INTEGER = '0'..'9'+;
$white $token WHITE_SPACES = ( ' ' | '\t' )+ ;

$parsable Example { expr:expr }

$abstract Expr { }
expr = term | Add | Sub ;
Add -> Expr { op1:expr "+" op2:term }
Sub -> Expr { op1:expr "-" op2:term }
term = prim
     | Mul -> Expr { op1:term "*" op2:prim }
     | Div -> Expr { op1:term "/" op2:prim } ;
prim = "(" $label:expr ")" | $label:Num ;
Num -> Expr { value:INTEGER }
```

The output from the above source is the following.

```
package parser;
public class Parser {
   Parser() { ... }
   public static abstract class LexicalAnalyzer { ... }
   protected LexicalAnalyzer
             createLexicalAnalyzer(...) { ... }
   public static interface Node {
      List getChildNodes(); ... }
   public static interface Token extends Node {
      String getImage();
      int getLine(); int getColumn(); ... }
   public Example parseExample(File file) { ... }
   public Example parseExample(LexicalAnalyzer la) {
      ... }
   ...
   public static interface Example extends Node {
      Expr expr(); ... }
   public static interface Expr extends Node { }
   public static interface Add extends Expr {
      Expr op1(); Expr op2(); ... }
   ...
}
```

The details are described in the javadoc comment of the generated file.

The CST for $1 * (2 + 3)$ is




The AST generated by removing the broken line boxes is