

Parse Tools

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Parse Tools 2.2
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1 Reference Manual

The **Parsetools** application contains utilities for parsing and scanning. Yecc is an LALR-1 parser generator for Erlang, similar to yacc. Yecc takes a BNF grammar definition as input, and produces Erlang code for a parser as output. Leex is a regular expression based lexical analyzer generator for Erlang, similar to lex or flex.

yecc

Erlang module

An LALR-1 parser generator for Erlang, similar to `yacc`. Takes a BNF grammar definition as input, and produces Erlang code for a parser.

To understand this text, you also have to look at the `yacc` documentation in the UNIX(TM) manual. This is most probably necessary in order to understand the idea of a parser generator, and the principle and problems of LALR parsing with finite look-ahead.

Exports

`file(Grammarfile [, Options]) -> YeccRet`

Types:

`Grammarfile = filename()`

`Options = Option | [Option]`

`Option = - see below -`

`YeccRet = {ok, Parserfile} | {ok, Parserfile, Warnings} | error | {error, Errors, Warnings}`

`Parserfile = filename()`

`Warnings = Errors = [{filename(), [ErrorInfo]}]`

`ErrorInfo = {ErrorLine, module(), Reason}`

`ErrorLine = integer()`

`Reason = - formatable by format_error/1 -`

`Grammarfile` is the file of declarations and grammar rules. Returns `ok` upon success, or `error` if there are errors. An Erlang file containing the parser is created if there are no errors. The options are:

`{parserfile, Parserfile}`.
: `Parserfile` is the name of the file that will contain the Erlang parser code that is generated. The default (`""`) is to add the extension `.erl` to `Grammarfile` stripped of the `.yrl` extension.

`{includefile, Includefile}`.
: Indicates a customized prologue file which the user may want to use instead of the default file `lib/parsetools/include/yeccpre.hrl` which is otherwise included at the beginning of the resulting parser file. **N.B.** The `Includefile` is included 'as is' in the parser file, so it must not have a module declaration of its own, and it should not be compiled. It must, however, contain the necessary export declarations. The default is indicated by `""`.

`{report_errors, bool()}`.
: Causes errors to be printed as they occur. Default is `true`.

`{report_warnings, bool()}`.
: Causes warnings to be printed as they occur. Default is `true`.

`{report, bool()}`.
: This is a short form for both `report_errors` and `report_warnings`.

`warnings_as_errors`
: Causes warnings to be treated as errors.

`{return_errors, bool()}`.
: If this flag is set, `{error, Errors, Warnings}` is returned when there are errors. Default is `false`.

`{return_warnings, bool()}`.
: If this flag is set, an extra field containing `Warnings` is added to the tuple returned upon success. Default is `false`.

`{return, bool()}`.
: This is a short form for both `return_errors` and `return_warnings`.

`{verbose, bool()}`.
: Determines whether the parser generator should give full information about resolved and unresolved parse action conflicts (`true`), or only about those conflicts that prevent a parser from being generated from the input grammar (`false`, the default).

Any of the Boolean options can be set to `true` by stating the name of the option. For example, `verbose` is equivalent to `{verbose, true}`.

The value of the `Parserfile` option stripped of the `.erl` extension is used by Yecc as the module name of the generated parser file.

Yecc will add the extension `.yrl` to the `Grammarfile` name, the extension `.hrl` to the `Includefile` name, and the extension `.erl` to the `Parserfile` name, unless the extension is already there.

`format_error(Reason) -> Chars`

Types:

`Reason = - as returned by yecc:file/1,2 -`

`Chars = [char() | Chars]`

Returns a descriptive string in English of an error tuple returned by `yecc:file/1,2`. This function is mainly used by the compiler invoking Yecc.

Pre-Processing

A `scanner` to pre-process the text (program, etc.) to be parsed is not provided in the `yecc` module. The scanner serves as a kind of lexicon look-up routine. It is possible to write a grammar that uses only character tokens as terminal symbols, thereby eliminating the need for a scanner, but this would make the parser larger and slower.

The user should implement a scanner that segments the input text, and turns it into one or more lists of tokens. Each token should be a tuple containing information about syntactic category, position in the text (e.g. line number), and the actual terminal symbol found in the text: `{Category, LineNumber, Symbol}`.

If a terminal symbol is the only member of a category, and the symbol name is identical to the category name, the token format may be `{Symbol, LineNumber}`.

A list of tokens produced by the scanner should end with a special `end_of_input` tuple which the parser is looking for. The format of this tuple should be `{Endsymbol, LastLineNumber}`, where `Endsymbol` is an identifier that is distinguished from all the terminal and non-terminal categories of the syntax rules. The `Endsymbol` may be declared in the grammar file (see below).

The simplest case is to segment the input string into a list of identifiers (atoms) and use those atoms both as categories and values of the tokens. For example, the input string `aaa bbb 777, X` may be scanned (tokenized) as:

```
[{aaa, 1}, {bbb, 1}, {777, 1}, {',' , 1}, {'X', 1},
 {'$end', 1}].
```

This assumes that this is the first line of the input text, and that `'$end'` is the distinguished `end_of_input` symbol.

The Erlang scanner in the `io` module can be used as a starting point when writing a new scanner. Study `yeccscan.erl` in order to see how a filter can be added on top of `io:scan_erl_form/3` to provide a scanner for Yecc that tokenizes grammar files before parsing them with the Yecc parser. A more general approach to scanner implementation is to use a scanner generator. A scanner generator in Erlang called `leex` is under development.

Grammar Definition Format

Erlang style `comments`, starting with a `'%'`, are allowed in grammar files.

Each `declaration` or `rule` ends with a dot (the character `'.'`).

The grammar starts with an optional `header` section. The header is put first in the generated file, before the module declaration. The purpose of the header is to provide a means to make the documentation generated by EDoc look nicer. Each header line should be enclosed in double quotes, and newlines will be inserted between the lines. For example:

```
Header "%% Copyright (C)"
"%% @private"
"%% @Author John".
```

Next comes a declaration of the `nonterminal categories` to be used in the rules. For example:

```
Nonterminals sentence nounphrase verbphrase.
```

A non-terminal category can be used at the left hand side (= `lhs`, or `head`) of a grammar rule. It can also appear at the right hand side of rules.

Next comes a declaration of the `terminal categories`, which are the categories of tokens produced by the scanner. For example:

```
Terminals article adjective noun verb.
```

Terminal categories may only appear in the right hand sides (= `rhs`) of grammar rules.

Next comes a declaration of the `rootsymbol`, or start category of the grammar. For example:

```
Rootsymbol sentence.
```

This symbol should appear in the lhs of at least one grammar rule. This is the most general syntactic category which the parser ultimately will parse every input string into.

After the rootsymbol declaration comes an optional declaration of the `end_of_input` symbol that your scanner is expected to use. For example:

```
Endsymbol '$end'.
```

Next comes one or more declarations of `operator precedences`, if needed. These are used to resolve shift/reduce conflicts (see `yacc` documentation).

Examples of operator declarations:

```
Right 100 '='.
Nonassoc 200 '==' '=/='.
Left 300 '+'.
Left 400 '*'.
Unary 500 '-'.
```

These declarations mean that `'='` is defined as a `right associative binary` operator with precedence 100, `'=='` and `'=/='` are operators with `no associativity`, `'+'` and `'*'` are `left associative binary` operators, where `'*'` takes precedence over `'+'` (the normal case), and `'-'` is a `unary` operator of higher precedence than `'*'`. The fact that '==' has no associativity means that an expression like `a == b == c` is considered a syntax error.

Certain rules are assigned precedence: each rule gets its precedence from the last terminal symbol mentioned in the right hand side of the rule. It is also possible to declare precedence for non-terminals, "one level up". This is practical when an operator is overloaded (see also example 3 below).

Next come the `grammar rules`. Each rule has the general form

```
Left_hand_side -> Right_hand_side : Associated_code.
```

The left hand side is a non-terminal category. The right hand side is a sequence of one or more non-terminal or terminal symbols with spaces between. The associated code is a sequence of zero or more Erlang expressions (with commas `','` as separators). If the associated code is empty, the separating colon `':'` is also omitted. A final dot marks the end of the rule.

Symbols such as `'{'`, `'.'`, etc., have to be enclosed in single quotes when used as terminal or non-terminal symbols in grammar rules. The use of the symbols `'$empty'`, `'$end'`, and `'$undefined'` should be avoided.

The last part of the grammar file is an optional section with Erlang code (= function definitions) which is included 'as is' in the resulting parser file. This section must start with the pseudo declaration, or key words

```
Erlang code.
```

No syntax rule definitions or other declarations may follow this section. To avoid conflicts with internal variables, do not use variable names beginning with two underscore characters ('__') in the Erlang code in this section, or in the code associated with the individual syntax rules.

The optional `expect` declaration can be placed anywhere before the last optional section with Erlang code. It is used for suppressing the warning about conflicts that is ordinarily given if the grammar is ambiguous. An example:

```
Expect 2.
```

The warning is given if the number of shift/reduce conflicts differs from 2, or if there are reduce/reduce conflicts.

Examples

A grammar to parse list expressions (with empty associated code):

```
Nonterminals list elements element.
Terminals atom '(' ')'.
Rootsymbol list.
list -> '(' ')'.
list -> '(' elements ')'.
elements -> element.
elements -> element elements.
element -> atom.
element -> list.
```

This grammar can be used to generate a parser which parses list expressions, such as `(), (a), (peter charles), (a (b c) d ((()))), ...` provided that your scanner tokenizes, for example, the input `(peter charles)` as follows:

```
[{'(', 1} , {atom, 1, peter}, {atom, 1, charles}, {')', 1},
 {'$end', 1}]
```

When a grammar rule is used by the parser to parse (part of) the input string as a grammatical phrase, the associated code is evaluated, and the value of the last expression becomes the value of the parsed phrase. This value may be used by the parser later to build structures that are values of higher phrases of which the current phrase is a part. The values initially associated with terminal category phrases, i.e. input tokens, are the token tuples themselves.

Below is an example of the grammar above with structure building code added:

```
list -> '(' ')' : nil.
list -> '(' elements ')' : '$2'.
elements -> element : {cons, '$1', nil}.
elements -> element elements : {cons, '$1', '$2'}.
element -> atom : '$1'.
element -> list : '$1'.
```

With this code added to the grammar rules, the parser produces the following value (structure) when parsing the input string `(a b c).`. This still assumes that this was the first input line that the scanner tokenized:

```
{cons, {atom, 1, a,} {cons, {atom, 1, b},
                            {cons, {atom, 1, c}, nil}}}
```

The associated code contains `pseudo variables '$1'`, `'$2'`, `'$3'`, etc. which refer to (are bound to) the values associated previously by the parser with the symbols of the right hand side of the rule. When these symbols are terminal categories, the values are token tuples of the input string (see above).

The associated code may not only be used to build structures associated with phrases, but may also be used for syntactic and semantic tests, printout actions (for example for tracing), etc. during the parsing process. Since tokens contain positional (line number) information, it is possible to produce error messages which contain line numbers. If there is no associated code after the right hand side of the rule, the value `'$undefined'` is associated with the phrase.

The right hand side of a grammar rule may be empty. This is indicated by using the special symbol `'$empty'` as rhs. Then the list grammar above may be simplified to:

```
list -> '(' elements ')' : '$2'.
elements -> element elements : {cons, '$1', '$2'}.
elements -> '$empty' : nil.
element -> atom : '$1'.
element -> list : '$1'.
```

Generating a Parser

To call the parser generator, use the following command:

```
yecc:file(Grammarfile).
```

An error message from Yecc will be shown if the grammar is not of the LALR type (for example too ambiguous). Shift/reduce conflicts are resolved in favor of shifting if there are no operator precedence declarations. Refer to the `yacc` documentation on the use of operator precedence.

The output file contains Erlang source code for a parser module with module name equal to the `Parserfile` parameter. After compilation, the parser can be called as follows (the module name is assumed to be `myparser`):

```
myparser:parse(myscanner:scan(Inport))
```

The call format may be different if a customized prologue file has been included when generating the parser instead of the default file `lib/parsetools/include/yeccpre.hrl`.

With the standard prologue, this call will return either `{ok, Result}`, where `Result` is a structure that the Erlang code of the grammar file has built, or `{error, {Line_number, Module, Message}}` if there was a syntax error in the input.

`Message` is something which may be converted into a string by calling `Module:format_error(Message)` and printed with `io:format/3`.

Note:

By default, the parser that was generated will not print out error messages to the screen. The user will have to do this either by printing the returned error messages, or by inserting tests and print instructions in the Erlang code associated with the syntax rules of the grammar file.

It is also possible to make the parser ask for more input tokens when needed if the following call format is used:

```
myparser:parse_and_scan({Function, Args})
myparser:parse_and_scan({Mod, Tokenizer, Args})
```

The tokenizer `Function` is either a fun or a tuple `{Mod, Tokenizer}`. The call `apply(Function, Args)` or `apply({Mod, Tokenizer}, Args)` is executed whenever a new token is needed. This, for example, makes it possible to parse from a file, token by token.

The tokenizer used above has to be implemented so as to return one of the following:

```
{ok, Tokens, Endline}
{eof, Endline}
{error, Error_description, Endline}
```

This conforms to the format used by the scanner in the Erlang `io` library module.

If `{eof, Endline}` is returned immediately, the call to `parse_and_scan/1` returns `{ok, eof}`. If `{eof, Endline}` is returned before the parser expects end of input, `parse_and_scan/1` will, of course, return an error message (see above). Otherwise `{ok, Result}` is returned.

More Examples

1. A grammar for parsing infix arithmetic expressions into prefix notation, without operator precedence:

```
Nonterminals E T F.
Terminals '+' '*' '(' ')' number.
Rootsymbol E.
E -> E '+' T: {'$2', '$1', '$3'}.
E -> T : '$1'.
T -> T '*' F: {'$2', '$1', '$3'}.
T -> F : '$1'.
F -> '(' E ')' : '$2'.
F -> number : '$1'.
```

2. The same with operator precedence becomes simpler:

```
Nonterminals E.
Terminals '+' '*' '(' ')' number.
Rootsymbol E.
Left 100 '+'.
Left 200 '*'.
E -> E '+' E : {'$2', '$1', '$3'}.
E -> E '*' E : {'$2', '$1', '$3'}.
E -> '(' E ')' : '$2'.
E -> number : '$1'.
```

3. An overloaded minus operator:

```
Nonterminals E uminus.
Terminals '*' '-' number.
Rootsymbol E.

Left 100 '-'.
Left 200 '*'.
Unary 300 uminus.

E -> E '-' E.
E -> E '*' E.
E -> uminus.
E -> number.

uminus -> '-' E.
```

4. The Yecc grammar that is used for parsing grammar files, including itself:

```
Nonterminals
grammar declaration rule head symbol symbols attached_code
token tokens.
Terminals
atom float integer reserved_symbol reserved_word string char var
'->' ':' dot.
Rootsymbol grammar.
Endsymbol '$end'.
grammar -> declaration : '$1'.
grammar -> rule : '$1'.
declaration -> symbol symbols dot: {'$1', '$2'}.
rule -> head '->' symbols attached_code dot: {rule, ['$1' | '$3'],
        '$4'}.
head -> symbol : '$1'.
symbols -> symbol : ['$1'].
symbols -> symbol symbols : ['$1' | '$2'].
attached_code -> ':' tokens : {erlang_code, '$2'}.
attached_code -> '$empty' : {erlang_code,
                 [{atom, 0, '$undefined'}]}.
tokens -> token : ['$1'].
tokens -> token tokens : ['$1' | '$2'].
symbol -> var : value_of('$1').
symbol -> atom : value_of('$1').
symbol -> integer : value_of('$1').
symbol -> reserved_word : value_of('$1').
token -> var : '$1'.
token -> atom : '$1'.
token -> float : '$1'.
token -> integer : '$1'.
token -> string : '$1'.
token -> char : '$1'.
token -> reserved_symbol : {value_of('$1'), line_of('$1')}.
token -> reserved_word : {value_of('$1'), line_of('$1')}.
token -> '->' : {'->', line_of('$1')}.
token -> ':' : {':', line_of('$1')}.
Erlang code.
value_of(Token) ->
    element(3, Token).
line_of(Token) ->
    element(2, Token).
```

Note:

The symbols `'->'`, and `':'` have to be treated in a special way, as they are meta symbols of the grammar notation, as well as terminal symbols of the Yecc grammar.

5. The file `erl_parse.yrl` in the `lib/stdlib/src` directory contains the grammar for Erlang.

Note:

Syntactic tests are used in the code associated with some rules, and an error is thrown (and caught by the generated parser to produce an error message) when a test fails. The same effect can be achieved with a call to `return_error(Error_line, Message_string)`, which is defined in the `yeccpre.hrl` default header file.

Files

```
lib/parsetools/include/yeccpre.hrl
```

See Also

Aho & Johnson: 'LR Parsing', ACM Computing Surveys, vol. 6:2, 1974.

leex

Erlang module

A regular expression based lexical analyzer generator for Erlang, similar to lex or flex.

> **Note:**
>
> The Leex module should be considered experimental as it will be subject to changes in future releases.

DATA TYPES

```
ErrorInfo = {ErrorLine,module(),error_descriptor()}
ErrorLine = integer()
Token = tuple()
```

Exports

`file(FileName) -> LeexRet`

`file(FileName, Options) -> LeexRet`

Types:

`FileName = filename()`

`Options = Option | [Option]`

`Option = - see below -`

`LeexRet = {ok, Scannerfile} | {ok, Scannerfile, Warnings} | error | {error, Errors, Warnings}`

`Scannerfile = filename()`

`Warnings = Errors = [{filename(), [ErrorInfo]}]`

`ErrorInfo = {ErrorLine, module(), Reason}`

`ErrorLine = integer()`

`Reason = - formatable by format_error/1 -`

Generates a lexical analyzer from the definition in the input file. The input file has the extension `.xrl`. This is added to the filename if it is not given. The resulting module is the Xrl filename without the `.xrl` extension.

The current options are:

`dfa_graph`

Generates a `.dot` file which contains a description of the DFA in a format which can be viewed with Graphviz, `www.graphviz.com`.

`{includefile,Includefile}`

Uses a specific or customised prologue file instead of default `lib/parsetools/include/leexinc.hrl` which is otherwise included.

`{report_errors, bool()}`

Causes errors to be printed as they occur. Default is `true`.

`{report_warnings, bool()}`

Causes warnings to be printed as they occur. Default is `true`.

`warnings_as_errors`

Causes warnings to be treated as errors.

`{report, bool()}`

This is a short form for both `report_errors` and `report_warnings`.

`{return_errors, bool()}`

If this flag is set, `{error, Errors, Warnings}` is returned when there are errors. Default is `false`.

`{return_warnings, bool()}`

If this flag is set, an extra field containing `Warnings` is added to the tuple returned upon success. Default is `false`.

`{return, bool()}`

This is a short form for both `return_errors` and `return_warnings`.

`{scannerfile, Scannerfile}`

`Scannerfile` is the name of the file that will contain the Erlang scanner code that is generated. The default (`""`) is to add the extension `.erl` to `FileName` stripped of the `.xrl` extension.

`{verbose, bool()}`

Outputs information from parsing the input file and generating the internal tables.

Any of the Boolean options can be set to `true` by stating the name of the option. For example, `verbose` is equivalent to `{verbose, true}`.

Leex will add the extension `.hrl` to the `Includefile` name and the extension `.erl` to the `Scannerfile` name, unless the extension is already there.

`format_error(ErrorInfo) -> Chars`

Types:

`Chars = [char() | Chars]`

Returns a string which describes the error `ErrorInfo` returned when there is an error in a regular expression.

The following functions are exported by the generated scanner.

Exports

`Module:string(String) -> StringRet`
`Module:string(String, StartLine) -> StringRet`

Types:

`String = string()`
`StringRet = {ok,Tokens,EndLine} | ErrorInfo`
`Tokens = [Token]`
`EndLine = StartLine = integer()`

Scans `String` and returns all the tokens in it, or an error.

> **Note:**
>
> It is an error if not all of the characters in `String` are consumed.

```
Module:token(Cont, Chars) -> {more,Cont1} | {done,TokenRet,RestChars}
Module:token(Cont, Chars, StartLine) -> {more,Cont1} |
{done,TokenRet,RestChars}
```

Types:

```
Cont = [] | Cont1
Cont1 = tuple()
Chars = RestChars = string() | eof
TokenRet = {ok, Token, EndLine} | {eof, EndLine} | ErrorInfo
StartLine = EndLine = integer()
```

This is a re-entrant call to try and scan one token from `Chars`. If there are enough characters in `Chars` to either scan a token or detect an error then this will be returned with `{done,...}`. Otherwise `{cont,Cont}` will be returned where `Cont` is used in the next call to `token()` with more characters to try an scan the token. This is continued until a token has been scanned. `Cont` is initially `[]`.

It is not designed to be called directly by an application but used through the i/o system where it can typically be called in an application by:

```
io:request(InFile, {get_until,unicode,Prompt,Module,token,[Line]})
  -> TokenRet
```

```
Module:tokens(Cont, Chars) -> {more,Cont1} | {done,TokensRet,RestChars}
Module:tokens(Cont, Chars, StartLine) -> {more,Cont1} |
{done,TokensRet,RestChars}
```

Types:

```
Cont = [] | Cont1
Cont1 = tuple()
Chars = RestChars = string() | eof
TokensRet = {ok, Tokens, EndLine} | {eof, EndLine} | ErrorInfo
Tokens = [Token]
StartLine = EndLine = integer()
```

This is a re-entrant call to try and scan tokens from `Chars`. If there are enough characters in `Chars` to either scan tokens or detect an error then this will be returned with `{done,...}`. Otherwise `{cont,Cont}` will be returned where `Cont` is used in the next call to `tokens()` with more characters to try an scan the tokens. This is continued until all tokens have been scanned. `Cont` is initially `[]`.

This functions differs from `token` in that it will continue to scan tokens upto and including an `{end_token,Token}` has been scanned (see next section). It will then return all the tokens. This is typically used for scanning grammars like Erlang where there is an explicit end token, `'.'`. If no end token is found then the whole file will be scanned and returned. If an error occurs then all tokens upto and including the next end token will be skipped.

It is not designed to be called directly by an application but used through the i/o system where it can typically be called in an application by:

```
io:request(InFile, {get_until,unicode,Prompt,Module,tokens,[Line]})
  -> TokensRet
```

Input File Format

Erlang style comments starting with a % are allowed in scanner files. A definition file has the following format:

```
<Header>

Definitions.

<Macro Definitions>

Rules.

<Token Rules>

Erlang code.

<Erlang code>
```

The "Definitions.", "Rules." and "Erlang code." headings are mandatory and must occur at the beginning of a source line. The <Header>, <Macro Definitions> and <Erlang code> sections may be empty but there must be at least one rule.

Macro definitions have the following format:

```
NAME = VALUE
```

and there must be spaces around `=`. Macros can be used in the regular expressions of rules by writing `{NAME}`.

Note:

When macros are expanded in expressions the macro calls are replaced by the macro value without any form of quoting or enclosing in parentheses.

Rules have the following format:

```
<Regexp> : <Erlang code>.
```

The <Regexp> must occur at the start of a line and not include any blanks; use `\t` and `\s` to include TAB and SPACE characters in the regular expression. If <Regexp> matches then the corresponding <Erlang code> is evaluated to generate a token. With the Erlang code the following predefined variables are available:

`TokenChars`

A list of the characters in the matched token.

`TokenLen`

The number of characters in the matched token.

`TokenLine`

The line number where the token occurred.

The code must return:

`{token,Token}`

Return `Token` to the caller.

`{end_token,Token}`

Return `Token` and is last token in a tokens call.

`skip_token`

Skip this token completely.

`{error,ErrString}`

An error in the token, `ErrString` is a string describing the error.

It is also possible to push back characters into the input characters with the following returns:

- `{token,Token,PushBackList}`
- `{end_token,Token,PushBackList}`
- `{skip_token,PushBackList}`

These have the same meanings as the normal returns but the characters in `PushBackList` will be prepended to the input characters and scanned for the next token. Note that pushing back a newline will mean the line numbering will no longer be correct.

Note:

Pushing back characters gives you unexpected possibilities to cause the scanner to loop!

The following example would match a simple Erlang integer or float and return a token which could be sent to the Erlang parser:

```
D = [0-9]

{D}+ :
  {token,{integer,TokenLine,list_to_integer(TokenChars)}}.

{D}+\.{D}+((E|e)(\+|\-)?{D}+)? :
  {token,{float,TokenLine,list_to_float(TokenChars)}}.
```

The Erlang code in the "Erlang code." section is written into the output file directly after the module declaration and predefined exports declaration so it is possible to add extra exports, define imports and other attributes which are then visible in the whole file.

Regular Expressions

The regular expressions allowed here is a subset of the set found in `egrep` and in the AWK programming language, as defined in the book, The AWK Programming Language, by A. V. Aho, B. W. Kernighan, P. J. Weinberger. They are composed of the following characters:

`c`

Matches the non-metacharacter c.

`\c`

Matches the escape sequence or literal character c.

`.`

Matches any character.

`^`

Matches the beginning of a string.

`$`

Matches the end of a string.

`[abc...]`

Character class, which matches any of the characters `abc...`. Character ranges are specified by a pair of characters separated by a `-`.

`[^abc...]`

Negated character class, which matches any character except `abc...`.

`r1 | r2`

Alternation. It matches either `r1` or `r2`.

`r1r2`

Concatenation. It matches `r1` and then `r2`.

`r+`

Matches one or more `rs`.

`r*`

Matches zero or more `rs`.

`r?`

Matches zero or one `rs`.

`(r)`

Grouping. It matches `r`.

The escape sequences allowed are the same as for Erlang strings:

`\b`

Backspace.

`\f`

Form feed.

`\n`

Newline (line feed).

`\r`

Carriage return.

`\t`

Tab.

`\e`

Escape.

`\v`

Vertical tab.

`\s`

Space.

`\d`

Delete.

`\ddd`

The octal value `ddd`.

`\xhh`

The hexadecimal value `hh`.

`\x{h...}`

The hexadecimal value `h...`.

\c

Any other character literally, for example \\ for backslash, \" for ".

The following examples define simplified versions of a few Erlang data types:

```
Atoms [a-z][0-9a-zA-Z_]*

Variables [A-Z_][0-9a-zA-Z_]*

Floats (\+|-)?[0-9]+\.[0-9]+((E|e)(\+|-)?[0-9]+)?
```

Note:

Anchoring a regular expression with ^ and $ is not implemented in the current version of Leex and just generates a parse error.