

Lex

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Modern Formal Language Theory, 2007

Lex

- tool for generating scanners
- scanner described by rules in a definition file
- a rule is a pair
 - lexical pattern (described by regular expression)
 - action (written in C)
- Lex processes the definition file and outputs a scanner written in C
- this scanner can be compiled by a C compiler to produce an executable
- the executable processes its input, finds lexical patterns and executes associated actions to produce its output

Definition file → Lex → Scanner in C → C compiler → Executable

Input → Executable → Output

Structure of Definition File – Example

Example

```
int num_lines = 0, num_chars = 0;
```

```
%%
```

```
\n    ++num_lines; ++num_chars;
```

```
.    ++num_chars;
```

```
%%
```

```
main()
```

```
{
```

```
    yylex();
```

```
    printf( "# of lines = %d, # of chars = %d\n",  
            num_lines, num_chars );
```

```
}
```

Structure of Definition File

- Lex definition file divided into 3 parts which are separated by %%:

- 1** definitions – definitions of global user variables, name definitions and start conditions

```
int num_lines = 0, num_chars = 0;
```

- 2** rules – patterns at the beginning of a line and indented actions which are executed when the corresponding pattern is matched with the source. Any non-matched character is copied to the resulting file

```
\n      ++num_lines; ++num_chars;  
      ++num_chars;
```

- 3** user code – any auxiliary C function used in rules and main().
yylex() is used to start the lexical analysis

```
main()  
{  
  yylex();  
  printf( "# of lines = %d, # of chars = %d\n",  
          num_lines, num_chars );  
}
```

Name Definitions

- used to declare symbolic names for regular expressions
- are of the form `name definition`

Example

`DIGIT` `[0-9]`

`ID` `[a-z][a-z0-9]*`

can be referenced as

`{DIGIT}+ "." {DIGIT}*`

which is identical to

`([0-9])+ "." ([0-9])*`

Regular Expressions I

- patterns described by regular expressions

Regular Expressions

`x` match the character `x`

`.` any character except newline

`[xyz]` a “character class”; the pattern matches either `x`, `y`, or `z`

`[abj-oZ]` a “character class” with a range in it; matches `a`, `b`, any letter from `j` through `o`, or `Z`

`[^A-Z]` a “negated character class”, i.e., any character but those in the class. In this case, any character except an uppercase letter

`[^A-Z\n]` any character except an uppercase letter or a newline

`r*` zero or more `r`'s, where `r` is any regular expression

`r+` one or more `r`'s

Regular Expressions II

Regular Expressions

`r?` zero or one `r`'s

`r{2,5}` anywhere from 2 to 5 `r`'s

`r{2,}` 2 or more `r`'s

`r{4}` exactly 4 `r`'s

`{name}` the expansion of the `name` definition

`"[xyz]"` the literal string: `[xyz]"`

`\x` if `x` is `a`, `b`, `f`, `n`, `r`, `t`, or `v`, then the ANSI-C interpretation of `\x`. Otherwise, a literal `x` (used to escape operators such as `*`)

`\0` a NUL character (ASCII code 0)

`\123` the character with octal value 123

`\x2a` the character with hexadecimal value 2a

Regular Expressions III

Regular Expressions

(*r*) match an *r*; parentheses are used to override precedence

rs the regular expression *r* followed by the regular expression *s*

r|s either *r* or *s*

^r an *r*, but only at the beginning of a line

r\$ an *r*, but only at the end of a line

<s>r an *r*, but only in start condition *s*; *<s1,s2,s3>r* same, but in any of start conditions *s1*, *s2*, or *s3*

<>r* an *r* in any start condition, even an exclusive one

<<EOF>> an end-of-file

<s1,s2><<EOF>> an end-of-file when in start condition *s1* or *s2*

Regular Expressions IV

Operator precedence

- operators described above grouped by precedence – highest first
- e.g., `foo|bar*` is the same as `(foo)|(ba(r*))`

Character Class Expressions

- `[:alnum:]`, `[:alpha:]`, `[:blank:]`, `[:cntrl:]`, `[:digit:]`,
`[:graph:]`, `[:lower:]`, `[:print:]`, `[:punct:]`, `[:space:]`,
`[:upper:]`, `[:xdigit:]`
- set of characters equivalent to the corresponding standard C `isXXX` function (e.g., `isalnum()`)

Input Matching

Input Matching Rules

- if no match found, the next character from the input is copied to the output
- if more than one match found, the longest string is chosen
- if there are more longest strings, the pattern appearing first in the definition file is chosen
- associated action is executed and the remaining input is scanned for the next match

Global Variables

- can be used in actions

`yytext` matched string

`yylen` length of the matched string

Actions I

- an action is a C code which follows the associated pattern
- if no action is specified, the matched string is discarded

```
%%
```

```
/* replace sequence of tabs with space */
```

```
[\t]+          putchar( ' ' );
```

```
[\t]+$        /* ignore tabs at the EOL */
```

- if multi-line action is needed, it has to be enclosed within { } or %{ %}
- the action | is used to specify the same action as the action for the next rule

Special Directives Used within Actions

ECHO copies ytext to the scanner's output

BEGIN used to place scanner to a start position

Actions II

Special Directives Used within Actions

REJECT directs the scanner to proceed on to the second best rule which matched the input

Example

```
int word_count = 0;
%%
        /* call special() for 'frob' */
frob      special(); REJECT;
        /* count the number of words */
[ ^ \t\n ]+  ++word_count;
```

Actions III

Example

```
%%  
a      |  
ab     |  
abc    |  
abcd   ECHO; REJECT;
```

- outputs abcdabcbaba for the input abcd

Special Directives Used within Actions

`yymore()` tells the scanner that the next time it matches a rule, the corresponding token should be appended onto the current value of `yytext` rather than replacing it

Actions IV

Example

```
%%  
mega-      ECHO; yymore();  
kludge     ECHO;
```

- outputs mega-mega-kludge for the input mega-kludge

Special Directives Used within Actions

`yyless(n)` returns all but the first `n` characters of the current token back to the input stream (will be rescanned)

`unput(c)` puts the character `c` back onto the input stream. It will be the next character scanned

`input()` reads the next character from the input stream

Start Conditions

- mechanism for conditionally activating and deactivating rules
- if a pattern is prefixed by <sc>, it will only be active when the scanner is in the start condition named sc

Example

```
<STRING>[~"]*           { /* eat up the string body ... */
```

is active only if the scanner is in the STRING start condition, and

```
<INITIAL,STRING,QUOTE>\. { /* handle an escape ... */
```

is active only if the scanner is either in INITIAL, STRING, or QUOTE condition

Start Condition Declaration

- start conditions declared in the first section
- activated by BEGIN action so rules with the given start condition will be active and rules with other start conditions will be inactive

Types of Start Conditions

inclusive (declared with %s) – also rules with no start condition are active

exclusive (declared with %x) – only rules with the given start condition are active (possible to define “mini-scanners” independent on the rest of the scanner)

- with the start condition INITIAL, only rules without start conditions are active
- <*> matches every start condition
- current start condition can be accessed by YY_START

Start Condition Example I

Example

```
%s example
```

```
%%  
<example>foo    do_something();  
bar             something_else();
```

is equivalent to

```
%x example
```

```
%%  
<example>foo    do_something();  
<INITIAL,example>bar    something_else();
```

Start Condition Example II

- several start conditions can be grouped

Example

- a (sub)scanner which discards C comments

%x comment

%%

```
int line_num = 1;
```

```
"/*" BEGIN(comment);
```

```
<comment>{
```

```
    [^*\n]*          /* eat anything that's not a '*' */
```

```
    "*" + [^*/\n]*    /* eat up '*'s not followed by '/'s */
```

```
    \n                ++line_num;
```

```
    "*" + "/"         BEGIN(INITIAL);
```

```
}
```

Generated Scanner

- output is written to yyout (lex.yy.c by default)
- it contains the routine `int yylex(void)` which runs the lexical analysis
- `int yylex(void)` can be changed by redefining `YY_DECL` macro

Example

```
#define YY_DECL float lexscan( float a, float b );
```

defines the scanning routine `lexscan` which takes two float parameters and returns float

- `yylex()` scans the global input file `yyin` (`stdin` by default)
- if it is not interrupted by a return statement (scanning can be resumed by calling `yylex()` again), it continues until it reaches EOF (returns 0)
- `yyrestart(FILE *)` can be used to continue scanning a new file

Command Line Options

```
flex [-bcdfhilnpstvwBFILTV78+? -C[aefFmr] -ooutput -Pprefix  
-Sskeleton] [--help --version] [file ...]
```

Selected Parameters

- o outf output file name
- P pref specifies prefix other than yy for Lex functions
 - i case insensitive scanner

Options Within Definition File

- many options can be specified within the first section of the definition file
 - %option case-insensitive

Example I

Example

```
/* scanner for a toy Pascal-like language */
```

```
%{
```

```
/* need this for the call to atof() below */
```

```
#include <math.h>
```

```
%}
```

```
DIGIT      [0-9]
```

```
ID         [a-z][a-z0-9]*
```

```
%%
```

Example II

Example

```
{DIGIT}+ {  
    printf( "An integer: %s (%d)\n", yytext,  
           atoi( yytext ) );  
}
```

```
{DIGIT}+"."{DIGIT}* {  
    printf( "A float: %s (%g)\n", yytext,  
           atof( yytext ) );  
}
```

```
if|then|begin|end|procedure|function {  
    printf( "A keyword: %s\n", yytext );  
}
```

Example III

Example

```
{ID}      printf( "An identifier: %s\n", yytext );
```

```
"+"|"-"|"*"|"/"
```

```
      printf( "An operator: %s\n", yytext );
```

```
"{"[^}\n]*"}"
```

```
      /* eat up one-line comments */
```

```
[ \t\n]+
```

```
      /* eat up whitespace */
```

```
.      printf( "Unrecognized character: %s\n", yytext );
```

```
%%
```


Example IV

Example

```
main( int argc, char ** argv )
{
    ++argv, --argc; /* skip over program name */
    if ( argc > 0 )
        yyin = fopen( argv[0], "r" );
    else
        yyin = stdin;

    yylex();
}
```


Bibliography

 Flex documentation.
<http://flex.sourceforge.net/manual/>.