Lex

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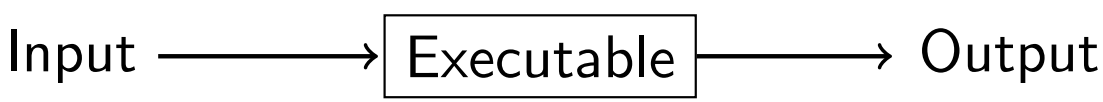
Lex

- 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



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

`yyleng` 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 `yytext` 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 abcdabcaba 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/`.