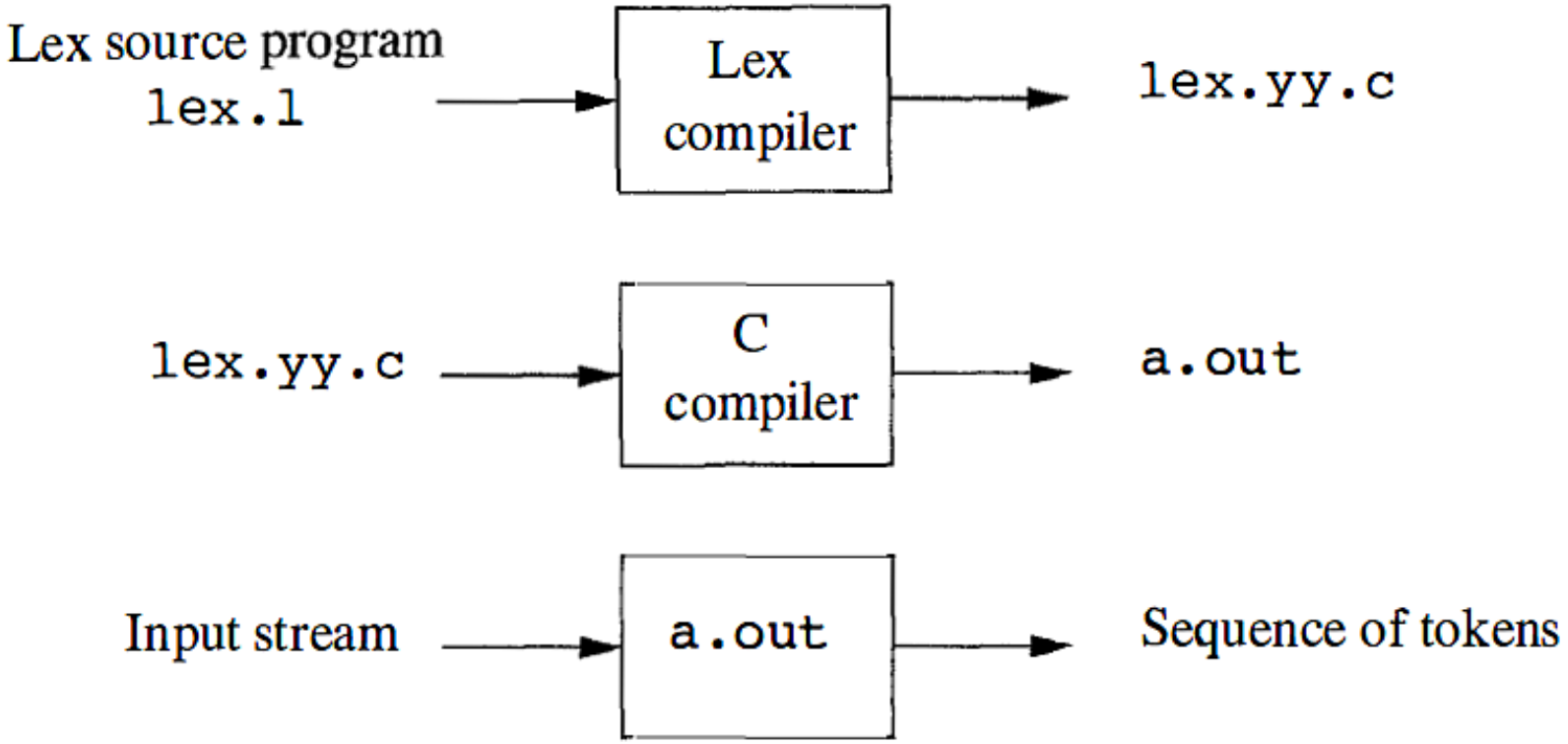
Introduction to Lex

Overview

- Lex is a tool for creating lexical analyzers.
- Lex source is a table of regular expressions and corresponding program fragments.
- The recognition of the expressions is performed by a deterministic finite automaton.
- As each expression appears in the input, the corresponding fragment is executed.

Usage Paradigm of Lex



Structure of Lex Programs

```
%{
        C declarations and includes
%}

declarations
%%
translation rules
%%
user subroutines
```

Structure of Lex Programs Cont'd

- %{…%}: Anything within these brackets i s copied directly to the file lex.yy.c
- Declarations: variables, identifiers declared to stand for a constant, and regular definitions
- Translation rules: pattern descriptions and actions

  Pattern { Action}
- User subroutines: user-written codes
- Three parts are separated by %%

Policy for None-translated Source

- Any source not intercepted by Lex is **copied** into the generated program.
  - Any line which is not part of a Lex rule or action which begins with a blank or tab
  - Anything included between lines containing only %{ and %}
  - Anything after the second %% delimiter

Position of Copied Source

- source input prior to the first %%
  - external to any function in the generated code
- after the first %% and prior to the second %%
  - appropriate place for declarations in the function generated by Lex which contains the actions
- after the second %%
  - after the Lex generated output

Default Rules and Actions

- The first and second part must exist, but may be empty, the third part and the second %% are optional.
- If the third part dose not contain a main(), a default main() will be linked.
- Unmatched patterns will perform a default action, which copys the input to the output

Simple Lex Source Examples

- A minimum Lex program:

```
%%
```

  It only copies the input to the output unchanged.

- Deleting three spacing characters:

```
%%
[ \t\n];
```

- Deleting all blanks and tabs at the ends of lines :

```
%%
[ \t]+$;
```

A Lex Source Example

```
%{
/*
* Example lex source file
* This first section contains necessary
* C declarations and includes
* to use throughout the lex specifications.
*/
#include <stdio.h>
%}

bin_digit [01]
%%
```

A Lex Source Example Cont'd

```
{bin_digit}* {
/* match all strings of 0's and 1's */
/* Print out message with matching text */
printf("BINARY: %s\n", yytext);
}
([ab]*aa[ab]*bb[ab]*)|([ab]*bb[ab]*aa[ab]*) {
/* match all strings over (a,b) containing aa and bb */
printf("AABB\n");
}
\n ; /* ignore newlines */
```

A Lex Source Example Cont'd

```
%%
/*
* Now this is where you want your main program
*/
int main(int argc, char *argv[]) {
/*
* call yylex to use the generated lexer
*/
yylex();
/*
* make sure everything was printed
*/
fflush(yyout);
exit(0);
}
```

Lex Regular Expressions

- Elementary Operations
  - single characters
    - except “ \ . $ ^ [ ] - ? * + | ( ) / { } % < >
  - concatenation (putting characters together)
  - alternation (a|b|c)
    - [ab] == a|b
    - [a-k] == a|b|c|...|i|j|k
    - [a-z0-9] == any letter or digit
    - [^a] == any character but a
  - Kleene Closure (*)
  - Positive Closure (+)

Lex Regular Expressions Cont'd

- Special Operations
  - . matches any single character (except newline)
  - " and \ quote the part as text
  - \t tab
  - \n newline
  - \b backspace
  - \" double quote
  - \\ \
  - ? the preceding is optional
    - ab? == a|ab
    - (ab)? == ab|ε

Lex Regular Expressions Cont'd

- Special Operations Cont'd
  - ^ at the beginning of the line
  - $ at the end of the line, same as /\n
  - [^] anything except
    - \"[^\"]*\" is a double quoted string
  - {n,m} m through n occurrences
    - a{1,3} is a or aa or aaa
  - {definition} translation from definition
  - / matches only if followed by right part of /
    - 0/1 the 0 of 01 but not 02 or 03 or …
  - ( ) grouping

Regular Definitions

- NAME REGUGLAR_EXPRSSION
  - digs [0-9]+
  - integer {digs}
  - plainreal {digs}"."{digs}
  - expreal {digs}"."{digs}[Ee][+-]?{digs}
  - real {plainreal}|{expreal}
- NAME must be a valid C identifier
- {NAME} is replaced by prior regular expression

Regular Definitions Cont'd

- The definitions can also contain variables and other declarations used by the Code generated by Lex.
  - These usually go at the start of this section, marked by %{ at the beginning and %} at the end or the line which begins with a blank or tab .
  - Includes usually go here.
  - It is usually convenient to maintain a line counter so that error messages can be keyed to the lines in which the errors are found.
    - %{
    - int linecount = 1;
    - %}

Translation Rules

- Pattern <white spaces> { program statements }
- A null statement will ignore the input
- Four special options:
  - The unmatched token is using a default action that ECHO from the input to the output
  - | indicates that the action for this rule is from the action for the next rule
  - REJECT means going to the next alternative
  - BEGIN means entering a start condition

Transition Rule Example

```
{real}      {return FLOAT;}
{newline}   {linecounter++;}
{integer}   {
        printf("I found an integer\n");
        return INTEGER;
        }
```

Ambiguous Source Rules

- When more than one expression can match the current input
  - The longest match is preferred.
  - Among rules which matched the same number of characters, the rule given first is preferred.

- To override the choice, use action REJECT

```
she     {s++; REJECT;}
he      {h++; REJECT;}
.|\n    ;
```

Multiple States

- Lex allows the user to explicitly declare multiple states (in Definitions section)

  %s COMMENT

- Default states is INITIAL or 0
- Transition rules can be classified into different states, which will be matched depending on the state in
- BEGIN is used to change state

```
<INITIAL>.          {ECHO;}
<INITIAL>"/*"       {BEGIN COMMENT;}
<COMMENT>.          {;}
<COMMENT>"*/"       {BEGIN INITIAL;}
```

Lex Special Variables

- yytext -- a string containing the lexeme
- yyleng -- the length of the lexeme
- yyin -- the input stream pointer

- Example:

```
{integer} {
  printf("I found an integer\n");
  sscanf(yytext,"%d", &x);
  return INTEGER;
}
```

Lex Library Function Calls

- yylex()
  - default main() contains a return yylex();
- yywarp()
  - called by lexical analyzer if end of the input file
  - default yywarp() always return 1
- yyless(n)
  - n characters in yytext are retained
- yymore()
  - the next input expression recognized is to be appended to the end of this input

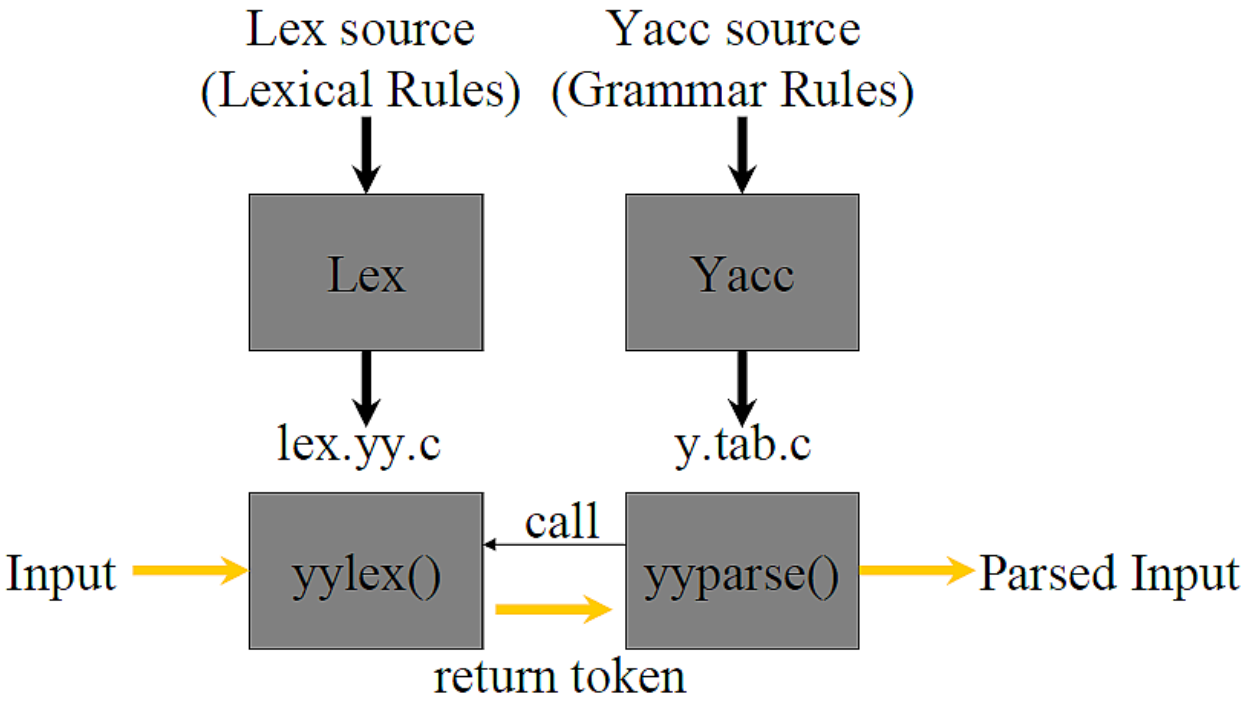
User Subroutines

- The actions associated with any given token are normally specified using statements in C. But occasionally the actions are complicated enough that it is better to describe them with a function call, and define the function elsewhere.
- Definitions of this sort go in the last section of the Lex input.

Example

```
%{ int lengs[100]; }%
%%
[a-z]+          { lengs[yyleng]++; }
.               |
\n              ;
%%
yywrap()
{
   int i;
   printf("Length No. words\n");
   for(i=0; i<100; i++)
       if (lengs[i] > 0)
           printf("%5d%10d\n",i,lengs[i]); return(1);
}
```

Using Yacc Together with Lex



• Yacc will call yylex() to get the token from the input so that each Lex rule should end with:

return(token);

where the appropriate token value is returned.

Resources

- FLex Manual: http://flex.sourceforge.net/manual/
- Doug Brown, John Levine, and Tony Mason, “lex & yacc”, second edition, O'Reilly.
- Thomas Niemann, “A Compact Guide to Lex & Yacc”.
- Lex/Yacc Win32 port: http://www.monmouth.com/~wstreett/lex-yacc/lex-yacc.html
- Parser Generator: www.bumblebeesoftware.com