

The Flex Scanner Generator

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Debugging Flex



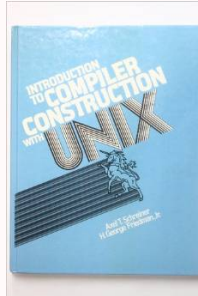
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1. Text Books



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2. Overview

- Historically, parsing was broken into phases; scanning and parsing were the first 2 phases.
- The scanner provided a sequence of tokens to the parser by reading characters from the input stream and building the tokens.
- flex is a **scanner generator**
- flex reads a spec describing the tokens, and then generates a scanner.



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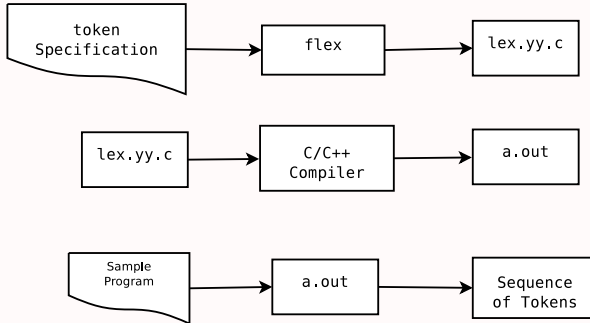
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2.1. Scanner Generation



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2.2. How it works

- flex generates `yylex`, a C fn that implements a DFA, based on the flex specification
- `yylex` reads from stdin and returns a number (token) associated with the matched pattern.
- To match more than one pattern, call `yylex` repeatedly (`yylex` returns 0 at eof):

```
int main() {  
    int token = yylex();  
    while ( token ) {  
        std::cout << "token: " << token << std::endl;  
        token = yylex();  
    }  
}
```



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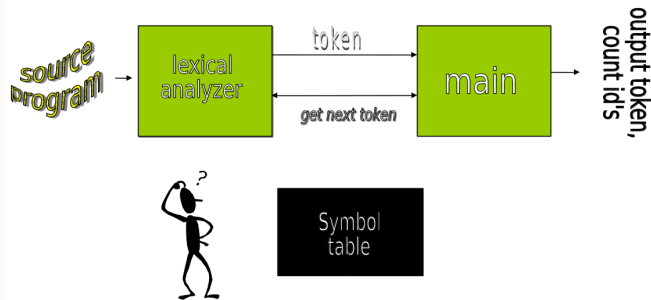
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2.3. Works with main or parser



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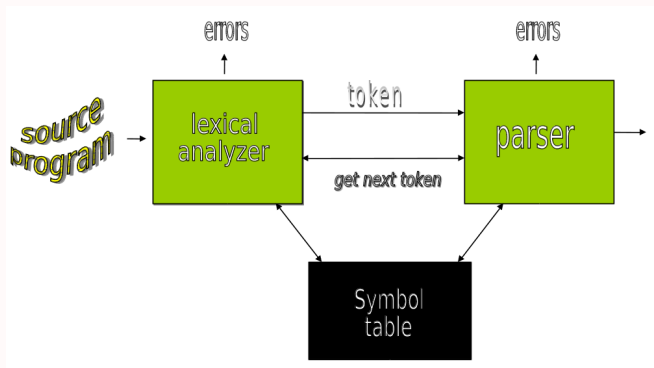
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2.4. Works with main or parser

- flex recognizes regular expressions.
- Need **bison** to recognize language constructs





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2.5. Lexical Analysis (scanner)

- Usually first phase in compilation
- Also used in editors, query language, testing, ...
- Approaches to building a scanner:
 - Write it by hand,
 - use a tool,
 - Incorporate into parser.

2.6. Tasks in Lexical Analysis

- Find extraneous chars,
- store names in symbol table,
- strip white space,
- recognize tokens.



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2.7. yywrap()

- called on eof by yylex;
 - if yywrap returns 1, then flex terminates;
 - Otherwise, flex makes another pass.

```
int yywrap() {  
    std::cout << "terminating flex" << std::endl;  
    return 1;  
}
```



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2.8. Makefile to use flex in debug mode

```
CCC = g++
LEX = flex
CXXFLAGS=-g -W -Wall -std=c++11 -Weffc++ -Wextra -O0

LEXFLAGS = -Wno-unused
FLEXDEBUG = -d
OBJS = main.o lex.yy.o

run: $(OBJS)
    $(CCC) $(CFLAGS) -o run $(OBJS)
main.o: main.cpp
    $(CCC) $(CFLAGS) -c main.cpp
lex.yy.c: scan.l
    $(LEX) $(FLEXDEBUG) -i scan.l
lex.yy.o: lex.yy.c
    $(CCC) $(CFLAGS) $(LEXFLAGS) -c lex.yy.c
```



2.9. Reading from a file

```
#include <iostream>
#include <fstream>

void main(int argc, char * argv[]) {
    if (argc != 2) {
        cout << "usage: " << argv[0] << "<filename>\n";
    }
    FILE * infile; // Must use C-style I/O
    infile = fopen(argv[1], "r");
    if (!infile) {
        cout << "Could not open: " << argv[1] << endl;
    }
    yyin = infile;
    yylex();
}
```

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3. Flex Sections

`%{`

C/C++ code

`%}`

Scanner declarations

`%%`

Token definitions and semantic actions

`%%`

C/C++ subroutines

(need prototype in C/C++ code section)



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A Simple Flex Example:

```
%{ // what does this program do?
%}

%%
"a"

%%
int yywrap() { return 1; }
```



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4. Regular Expressions

Flex characters have special meanings:

1. `.` matches any single char except newline
2. `[]` character class, matches any char w/in brackets; if first char is `^` it matches any char except those in bracket.
3. `^` matches the beginning of a line as first char in regular expr.
4. `$` matches the end of line as last char
5. `\` escapes metacharacters
6. `*` matches 0 or more
7. `+` matches 1 or more
8. `?` matches 0 or 1 occurrence
9. `|` is alternation

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10. `()` group

11. `{}` if numbers, specifies how many (`A{1, 3}` matches 1 to 3 consecutive A's), and (`A{2}` matches 2 consecutive A's)

12. `(?s:pattern)` apply option `s` while interpreting pattern. frequently used options:

- `i` \Rightarrow case insensitive;
- `-i` \Rightarrow case sensitive

13. `(?# comment)` \Rightarrow comments in specs

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Some Pattern Examples:

```
%{
#include <iostream>
%}

letter      [a-zA-Z]

%%

(?i:c)      { std::cout << "upper or lower case c" << std::endl; }
(?-i:d)     { std::cout << "only lower case d" << std::endl; }
(?-i:E)     { std::cout << "only upper case E" << std::endl; }
c           { std::cout << "never gets here!" << std::endl; }
ab          { std::cout << "Matching ab" << std::endl; }

%{ Question: %}
(?# why does it choose the next rule over first 3?)
~0          { std::cout << "match 0 at eol" << std::endl; }
{letter}$   { std::cout << "match 1 letter at eol" << std::endl; }
{letter}*   { std::cout << "bunches of letters" << std::endl; }
(?#: this is a comment)
.           { /* matches everything except \n */ }
```



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4.1. RE Examples

<code>a+b+</code>	1 or more a's, followed by 1 or more b's
<code>a b</code>	either an a or a b
<code>x</code>	the character x
<code>[abc]</code>	a, b, or c
<code>[0-9]+</code>	an integer
<code>[-+]?[0-9]+</code>	integer with opt sign (- must come 1st)
<code>[\t\n]</code>	whitespace
<code>[mM]</code>	use this rather than (?i:m)
<code>{word}</code>	whatever <i>word</i> is defined as
<code>^r</code>	an r, only at begin of line
<code>r\$</code>	an r, only at end of line
<code>r{3}</code>	exactly 3 r's
<code>r{1,3}</code>	1 to 3 r's
<code>r{2,}</code>	2 or more r's

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5. Ambiguity

- If multiple patterns match a given input:
 - Match longest string,
 - In case of tie, match first pattern in specification.

```
%%  
[0-9]+ { std::cout << "matched 9" << std::endl; }  
9      { std::cout << "no way!" << std::endl; }
```



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6. Start States

- Permits control of what gets matched when
- `\x` defines the **start state**
- When scanner is in a **state**, it can only match the patterns specified in that state.
- Can define as many start states as needed
- The macro **BEGIN** switches states
- **BEGIN(INITIAL)** or **BEGIN(0)** return to start state

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6.1. C Comments

`%x COMMENT`

`%%`

```
"/*"      { BEGIN(COMMENT); ++comments; }  
<COMMENT>"*/" { BEGIN(0); do_newline(); }  
<COMMENT>\n { do_newline(); }  
<COMMENT>. { ; }
```



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7. Debugging Flex

- The `-d` flag tells flex to go into debug mode:
`flex -d scan.l`
- Flex will then print the rules that are matched:

for `a+b+` on line 12, and `\n` on line 14:

```
aaab
--accepting rule at line 12 ("aaab")
match: aaab
--accepting rule at line 14 ("
")
```

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