Syntax Analysis

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Lecture #2 out of 10
80 minutes

The slidedeck was presented by the author in this YouTube Video

Chapter #1:

Extended Backus-Naur Form

In 1959, John Backus proposed a metalanguage to describe the syntax of IAL, known today as ALGOL 58. Further development of ALGOL led to ALGOL 60. In the committee's 1963 report, Peter Naur called Backus's notation Backus normal form. Donald Knuth argued that BNF should rather be read as Backus–Naur form, as it is "not a normal form in the conventional sense."

EBNF is now the way to specify formal grammars. Proposed by Niklaus Wirth in 1977 as an alternative to BNF.

The International Organization for Standardization adopted an EBNF Standard, ISO/IEC 14977, in 1996. However, there are many notations of EBNF.

This first published version looked like: `<number> ::= <digit> |<number> <digit>`
`<digit> ::= 0 |1 |2 |3 |4 |5 |6 |7 |8 |9`

Our language EBNF:

```
program = line { eol line };
line = number command arguments;
arguments = [ argument { "," argument } ];
number = digit { digit };
digit = "0" |$\vert$| "1" |$\vert$| "2" ... |$\vert$| "9";
eol = "\n";
```

Chapter #2:

Lexical Analysis

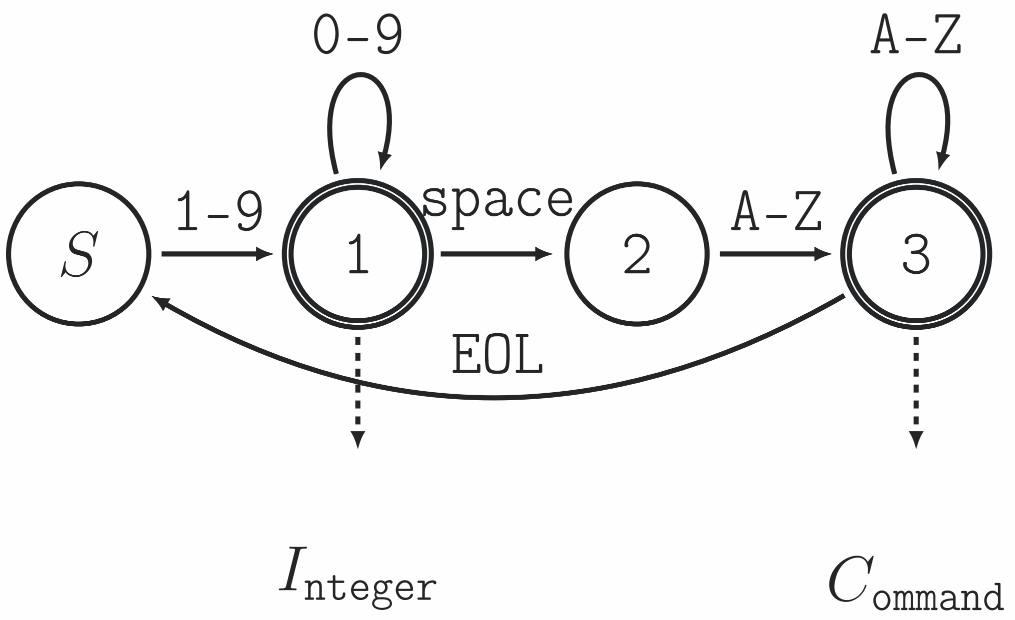
Lexical analyzer (*lexer* or *scanner*) takes input language and produces *tokens* (which then can be parsed into parse tree by a parser).

Lexemes are said to be a sequence of characters in a token.

Lexers are implemented as DFAs, which use regular expressions. For example, this is the language:

```
10 PRINT
20 RENDER
30 EXIT
```

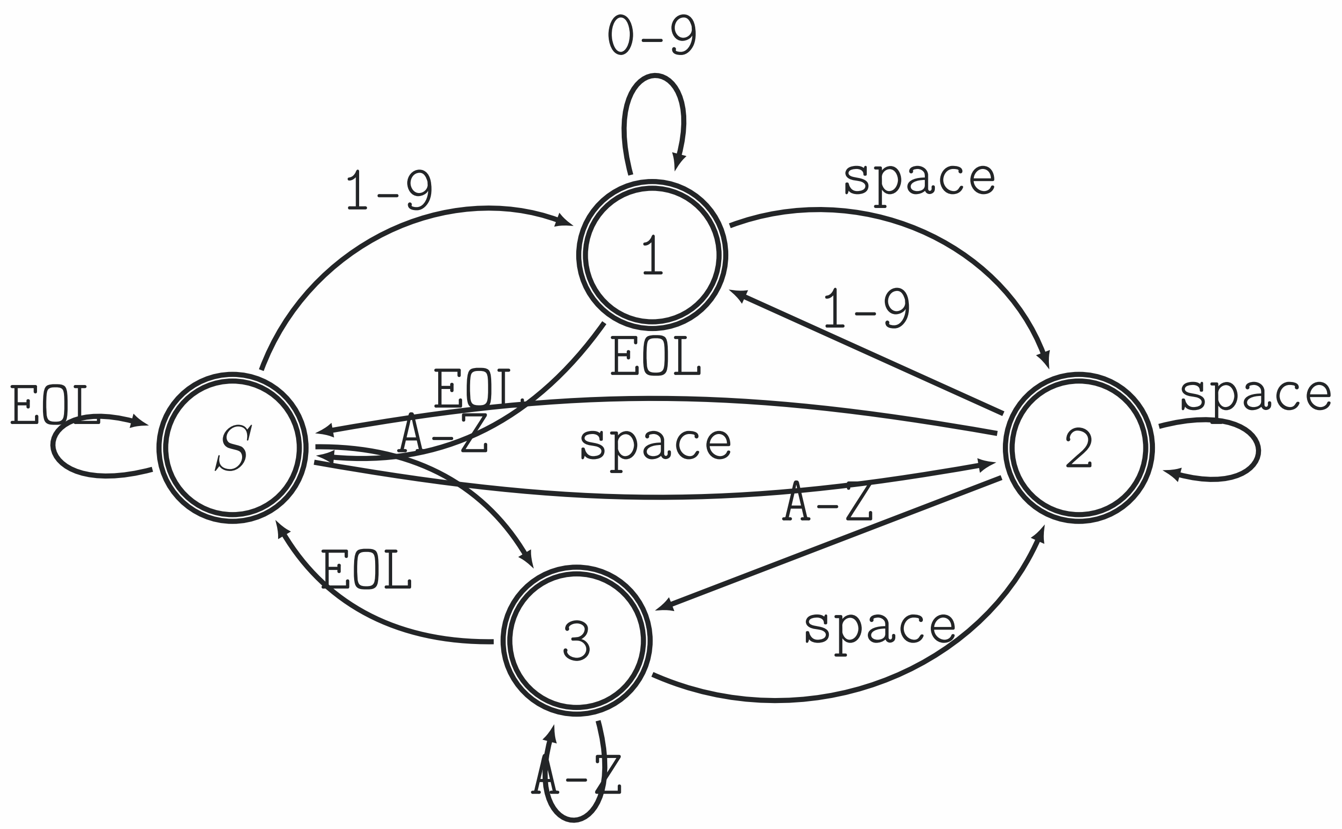
The DFA for this language (pattern matching rules on the edges):



The stream of tokens (with lexems inside them) produced:

```
Integer("10"), Command("PRINT"), Integer("20"),
Command("RENDER"), Integer("30"), Command("EXIT").
```

Some lexems (like spaces or EOLs) are ignored and do not become tokens. They are *non-token* elements. However, they could become tokens, like in this DFA:



Q: What would be the stream of tokens for `"10␣INPUT\n\n␣␣␣20"`?

Q: How many tokens in this C-language program?:

```
printf("age=%d", &i);
```

Chapter #3:

Syntactic Analysis

While *lemmatization* focuses purely on feature extraction and data cleaning, *syntactic analysis* analyzes the relationship between words and the grammatical structure of sentences.

Top-Down and Bottom-Up Parsing

Top-down parsing builds the parse tree from the top (start symbol) down; most top-down methods are LL. *Bottom-up parsing* builds the parse tree from the leaves (terminal symbols) up; most methods are LR.

LL means **L**eft-to-right + **L**eftmost derivation.

LR means **L**eft-to-right + **R**ightmost derivation.

Predictive Parsing

A *recursive descent parser* is the one the checks every rule before making a decision which one is right.

Predictive parsing is possible only for the class of $LL(k)$ grammars, which are the CFGs for which there exists some positive integer k that allows a parser to decide which production rule to use by examining only the next k tokens of input.

Flex and Bison

These tools are called *compiler-compilers* (originally `lex` and `yacc`) or parser generators.

Make this simple Flex program in `foo.x`:

```
%option noyywrap
DIGIT [0-9]
LETTER [a-z]
%%
{DIGIT}+ { printf( "int: %s\n", yytext ); }
{LETTER}+ { printf( "word: %s\n", yytext ); }
%%
int main(int argc, char** argv) { yylex(); }
```

Then, compile it with Flex and then with Gcc:

```
$ flex foo.x
$ gcc lex.yy.c
$ ./a.out
```

Each time the program needs a token, it calls `yylex()`, which reads a little input and returns the token. When it needs another token, it calls `yylex()` again. The scanner acts as a *coroutine*; that is, each time it returns, it remembers where it was, and on the next call it picks up where it left off.

The *action code* is what stays in the brackets after the *pattern*. If action code returns, scanning resumes on the next call to `yylex()`; if it doesn't return, scanning resumes immediately.

Lexical errors may be *handled* and the lexer may *recover* from some of them: we don't want the lexer to stop at the first error. See how Flex recovers.

This is Bison code in `foo.y`:

```
%token WORD
%token INT
%%
input: date |$\vert$| sentence;
date:
  INT INT INT
  { printf("date!\n"); };;
sentence:
  |$\vert$|
  sentence WORD
  { printf("sentence!\n"); };
%%
int main(int argc, char** argv) {
```

```
  yyparse();
}
void yyerror(char *s) {
  fprintf(stderr, "error: %s\n", s);
}
```

We compile them together as such:

```
bison -d foo.y
flex foo.x
gcc foo.tab.c lex.yy.c
```

Bison generates `foo.tab.h` file, which we must `#include` into `foo.x`.

ANTLR

ANTLR breaks the stream into tokens (capitalized names) and non-terminals:

```
grammar basic;
program: line+;
line: order command tail;
order: INTEGER;
command: NAME;
tail: argument*;
INTEGER: [1-9][0-9]*;
NAME: [A-Z]+;
SPACE: (' ')+ { skip(); };
```

References