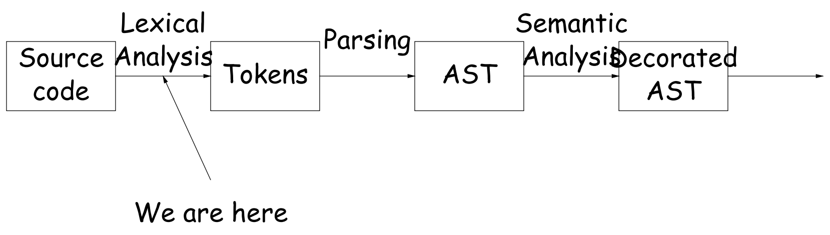
Lecture 2: Lexical Analysis

- Register yourself electronically using one of the "Account Administration" link on the class home page.
- You can also start adding yourself to a team (2–4 people) on this page.
- Please also add yourself to the Piazza newsgroup (link on home page).

Review: Front End Compiler Structure



- A sequence of translations that each:
  - Filter out errors
  - Remove or put aside extraneous information
  - Make data more conveniently accessible.
- Strategy: find tools that partially automate this procedure.
- For lexical analysis: convert description that uses patterns (extended regular expressions) into program.

Tokens

- Token consists of *syntactic category* (like "noun" or "adjective") plus *semantic information* (like a particular name).
- Parsing (the "customer") only needs syntactic category:
  - "Joe went to the store" and "Harry went to the beach" have same grammatical structure.
- For programming, semantic information might be text of identifier or numeral.
- Example from Notes:

```
if(i== j)
    z = 0;   /* No work needed */
else
    z= 1;
```

$\Longrightarrow$

```
IF, LPAR, ID("i"), EQUALS,
ID("j"), RPAR, ID("z"),
ASSIGN, INTLIT("0"), SEMI,
ELSE, ID("z"), ASSIGN,
INTLIT("1"), SEMI
```


Classical Regular Expressions

- Regular expressions denote formal languages, which are sets of strings (of symbols from some alphabet).
- Appropriate since internal structure not all that complex yet.
- Expression R denotes language $L(R)$:
  - $L(\epsilon) = L(\texttt{""}) = \{\texttt{""}\}$.
  - If c is a character, $L(c) = \{\texttt{"}c\texttt{"}\}$.
  - If R_1, R_2 are r.e.s, $L(R_1R_2) = \{x_1x_2 | x_1 \in L(R_1), x_2 \in L(R_2)\}$.
  - $L(R_1|R_2) = L(R_1) \cup L(R_2)$.
  - $L(R*) = L(\epsilon) \cup L(R) \cup L(R\ R) \cup \cdots$.
  - $L((R)) = L(R)$.
- Precedence is '*' (highest), concatenation, union (lowest). Parentheses also provide grouping.

Abbreviations

- Character lists, such as `[abcf-mxy]` in Java, Perl, or Python.
- Negative character lists, such as `[^aeiou]`.
- Character classes such as `.` (dot), `\d`, `\s` in Java, Perl, Python.
- $L(R^+) = L(RR*)$.
- $L(R?) = L(\epsilon|R)$.

Extensions

- "Capture" parenthesized expressions:
  - After `m = re.match(r'\s*(\d+)\s*,\s*(\d+)\s*', '12,34')`, have `m.group(1) == '12'`, `m.group(2) == '34'`.
- Lazy vs. greedy quantifiers:
  - `re.match(r'(\d+).*', '1234ab')` makes `group(1)` match '1234'.
  - `re.match(r'(\d+?).*', '1234ab')` makes `group(1)` match '1'.
- Boundaries:
  - `re.search(r'(^abc|qef)', L)` matches abc only at beginning of string, and qef anywhere.
  - `re.search(r'(?m)(^abc|qef)', L)` matches abc only at beginning of string or of any line.
  - `re.search(r'rowr(?=baz)', L)` matches an instance of 'rowr', but only if 'baz' follows (does not match baz).
  - `re.search(r'(?<=rowr)baz', L)` matches an instance of 'baz', but only if immediately preceded by 'rowr' (does not match rowr).
- Non-linear patterns: `re.search(r'(\S+),\1', L)` matches a word followed by the same word after a comma.

An Example

SL/1 "language":

```
+   -   *   /   =     ;   ,   (   )   <   >
>=  <=  -->
if  def  else fi  while
```

identifiers
decimal numerals

Comments start with # and go to end of line.
(*Review of programs in Chapter 2 of Course Notes.*)

Problems

- Decimal numerals in C, Java.
- All numerals in C, Java.
- Floating-point numerals.
- Identifiers in C, Java.
- Identifiers in Ada.
- Comments in C++, Java.
- XHTML markups.
- Python bracketing.

Some Problem Solutions

- Decimal numerals in *C*, Java: `0|[1-9][0-9]*`
- All numerals in *C*, Java: `[1-9][0-9]+|0[xX][0-9a-fA-F]+|0[0-7]*`
- Floating-point numerals: `(\d+\.\d*|\d*\.\d+)([eE][-+]?\d+)?|[0-9]+[eE][-`
- Identifiers in *C*, Java. (*ASCII only, no dollar signs*):
  `[a-zA-Z_][a-zA-Z_0-9]*`
- Identifiers in Ada: `[a-zA-Z]([a-zA-Z_0-9]|_[a-zA-Z0-9])*`
- Comments in *C*++, Java: `//.*|/\*([^*]|\*[^/])*\*+/`
  or, using some extended features: `//.*|/\*(.|\n)*?\*/`
- Python bracketing: *Nothing much you can do here, except to note blanks at the beginnings of lines and to do some programming in the actions.*