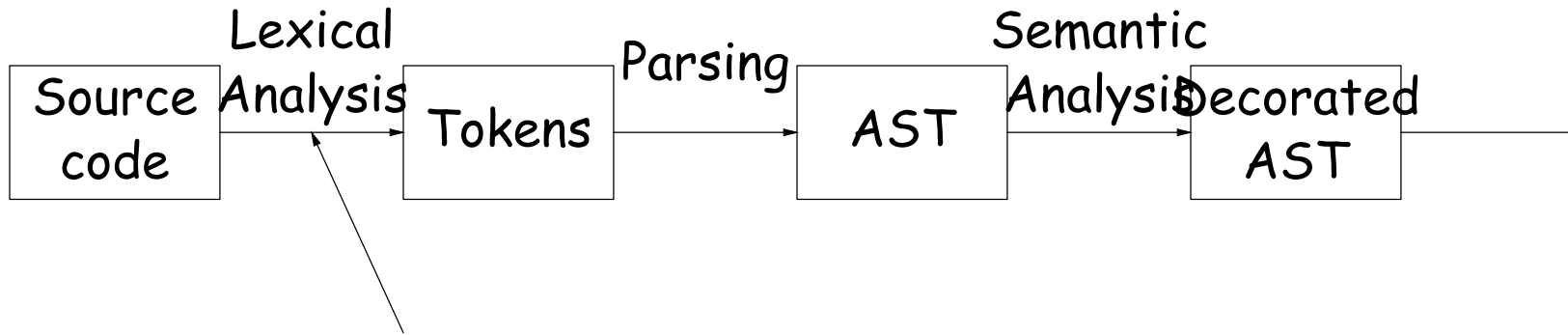# Lecture 2: Lexical Analysis

Administrivia

- Newsgroup appears to be functioning, now managed by CSUA. Visit

    `news.csua.berkeley.edu`

- Lecture page also has readings. Try to read once *before* lecture.

- Log into your class account ASAP (I still have account forms).

- Start forming teams:

    – Choose team name (letters, digits, underscores only, starting with capital letter)

    – Email me (`Hilfinger@cs.berkeley.edu`) name of team, and class logins of members (also mail changes).

- Good time to start learning Python (manuals online).

Review: Front End Compiler Structure

```
                Lexical                    Parsing          Semantic
 ┌────────┐    Analysis  ┌────────┐                 ┌──────┐ Analysis ┌───────────┐
 │ Source │─────────────▶│ Tokens │────────────────▶│ AST  │─────────▶│ Decorated │────────▶
 │  code  │              │        │                 │      │          │    AST    │
 └────────┘              └────────┘                 └──────┘          └───────────┘
       ▲
       │
   We are here
```

- 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 $L(R)$:

  - $L(\epsilon) = L("") = \{""\}$.
  - If c is a character, $L(c) = \{"c"\}$.
  - If R_1, R_2 are r.e.s, $L(R_1 R_2) = \{x_1 x_2 | x_1 \in L(R_1), x_2 \in L(R_2)\}$.
  - $L(R_1 | R_2) = L(R_1) \cup L(R_2)$.
  - $L(R*) = L(\epsilon) \cup L(R) \cup L(R\ R) \cup \cdots$.
  - $L((R)) = L(R)$.

- 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.

Review of Sample Programs

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.*