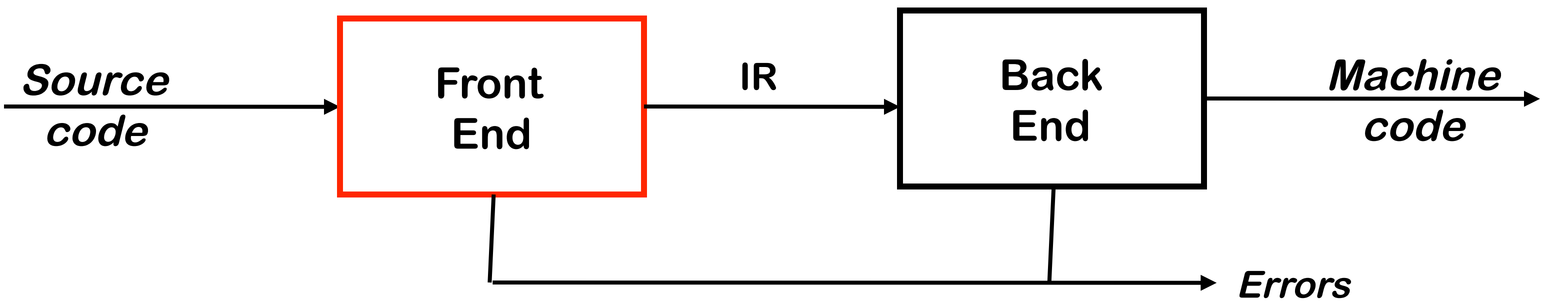
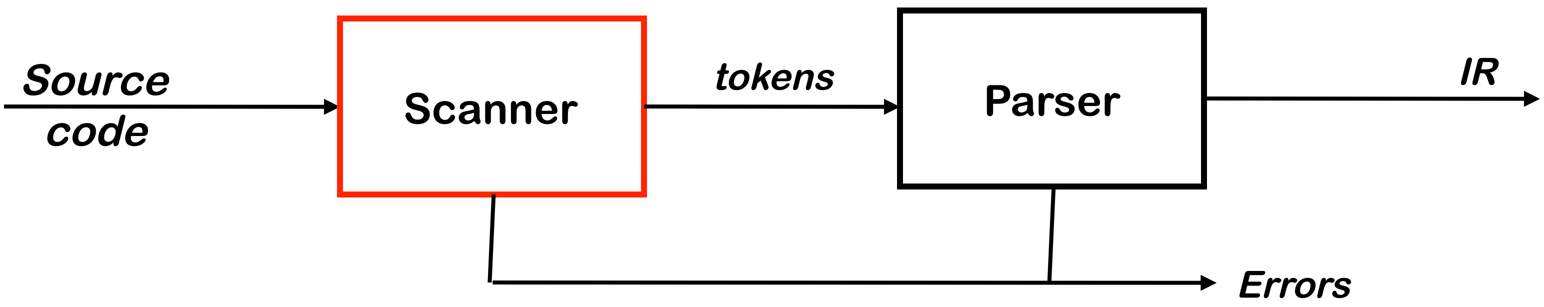
Lexical Analysis - An Introduction

The Front End



The front end is not monolithic

The Front End



Scanner

- Maps stream of characters into words
  - → Basic unit of syntax
  - → x = x + y ; *becomes set of tokens <type, lexeme>*

<id,x> <eq,=> <id,x> <pl,+> <id,y> <sc,; >

Where is Lexical Analysis Used?

For traditional languages but where else…

- Web page "compilation"
  - Lexical Analysis of HTML, XML, etc.
- Natural Language Processing
- Game Scripting Engines
- OS Shell Command Line
- GREP
- Prototyping high-level languages
- JavaScript, Perl, Python

The Big Picture

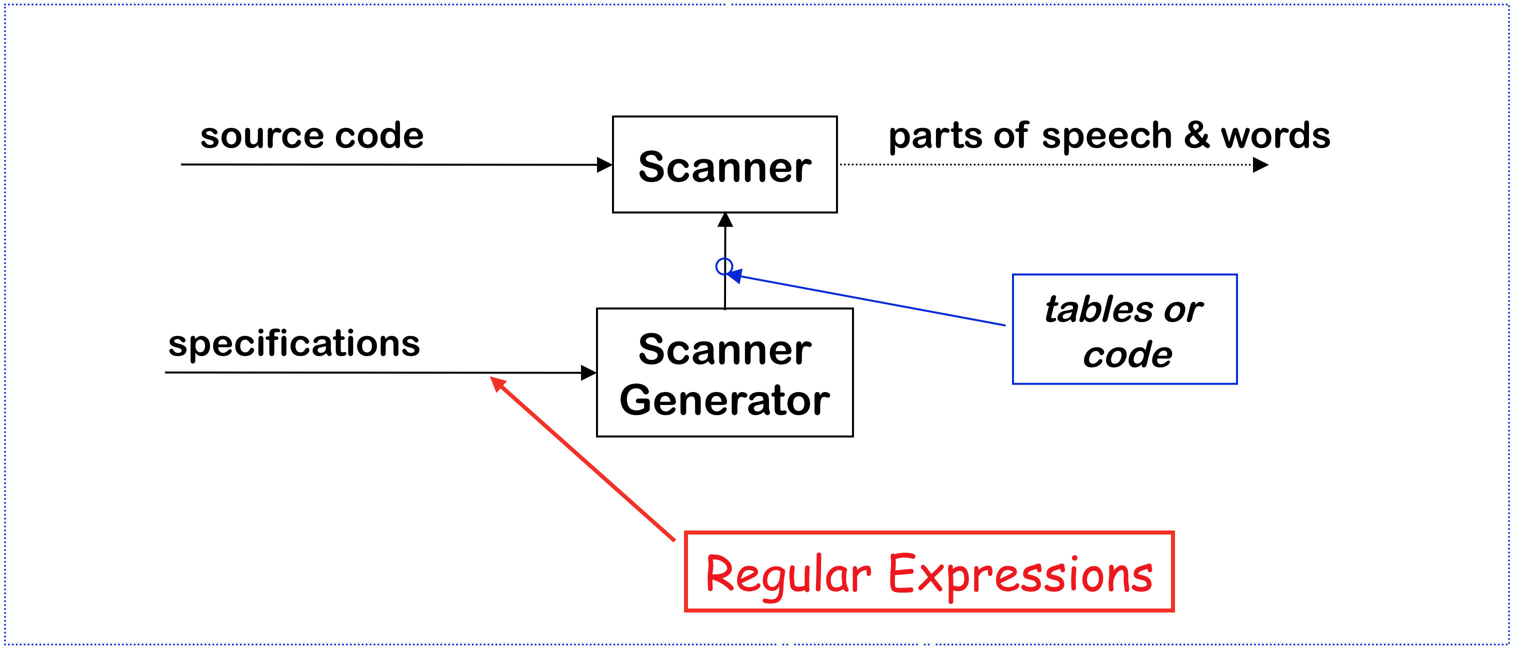
Why study lexical analysis?

- We want to avoid writing scanners by hand
- We want to harness the theory from classes like CISC 303

Goals:

→ To simplify specification & implementation of scanners

→ To understand the underlying techniques and technologies



Regular Expressions

Powerful notation to specify lexical rules

- Simplifies scanner construction
- Notation describes set of strings over some alphabet
- Entire set of strings called the **language**
- If r is an RE, L(r) is the language it specifies

Regular Expressions (more formally)

- Over some alphabet Σ
- ε is a RE denoting the empty set
- If a is in Σ, then a is a RE denoting {a}

Regular Expressions (more formally)

Given sets R and S

- *Closure:* R^* is an RE denoting

$$\cup_{0 \le i \le \infty} R^i$$

- *Concatenation:* RS is an RE denoting

$$\{st \mid s \in R \text{ and } t \in S\}$$

- *Alternation:* $R \mid S$ is an RE denoting

$$\{s \mid s \in R \text{ or } s \in S\}$$

  \- *Often written* $R \cup S$

Note: Precedence is *closure*, then *concatenation*, then *alternation*

Examples of Regular Expressions

Identifiers:

Letter → (a|b|c| … |z|A|B|C| … |Z)

Digit → (0|1|2| … |9)

Identifier → *Letter* (*Letter* | *Digit*)*

Numbers:

Integer → (+|-|ε) (0| (1|2|3| … |9)(*Digit* *))

Decimal → *Integer* . *Digit* *

Real → (*Integer* | *Decimal*) E (+|-|ε) *Digit* *

Complex → (*Real* , *Real*)

Numbers can get much more complicated!

Regular Expressions (the point)

REs are used to specify the words to be translated to parts of speech by a lexical analyzer

Using results from automata theory and theory of algorithms, we can **automatically** build **recognizers (i.e. scanners)** from regular expressions

You may have seen this construction in a Automata Course

⇒ We study REs and associated theory to automate scanner construction !

Regular Expression Class Problem?

What is the regular expression for a register name?

Examples: r1, r25, r999 ← These are OK.

r, s1, a25 ← These are not OK.

Register Name RE Solution

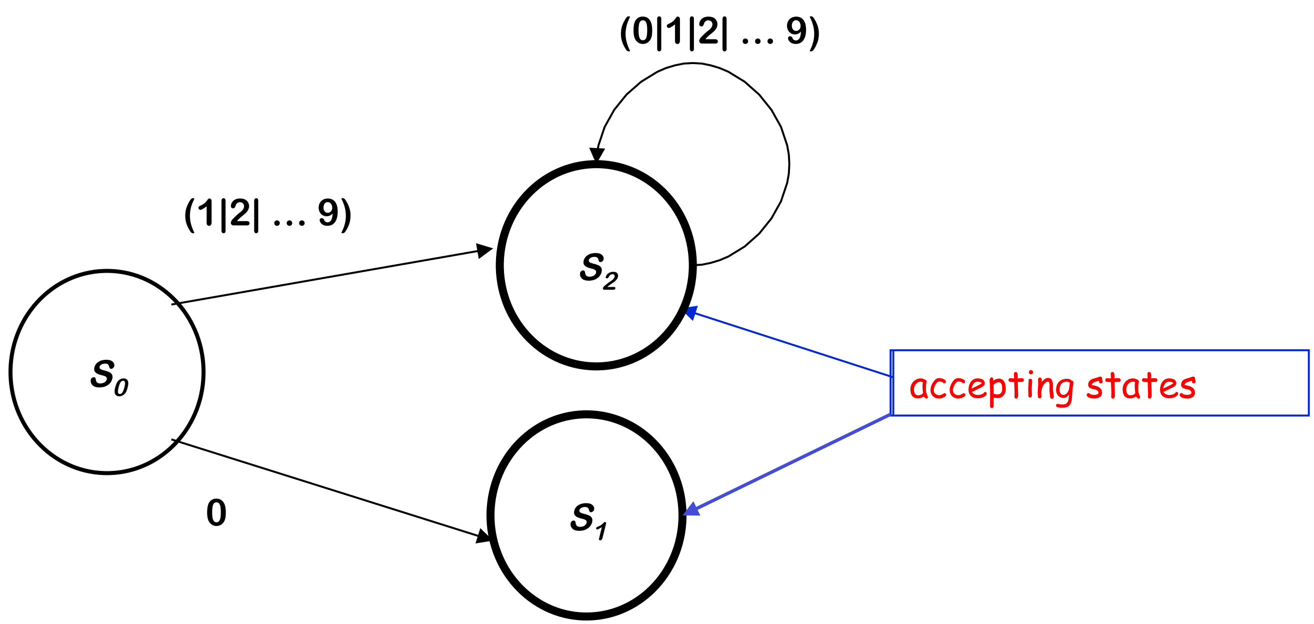
Consider the problem of recognizing register names

$$Register \rightarrow r\ (0|1|2|\ \ldots\ |\ 9)\ (0|1|2|\ \ldots\ |\ 9)^*$$

- Allows registers of arbitrary number
- Requires at least one digit

Finite Automaton (FA)

- An abstract machine that corresponds to a particular RE
- Recognizers can scan a stream of symbols to find words



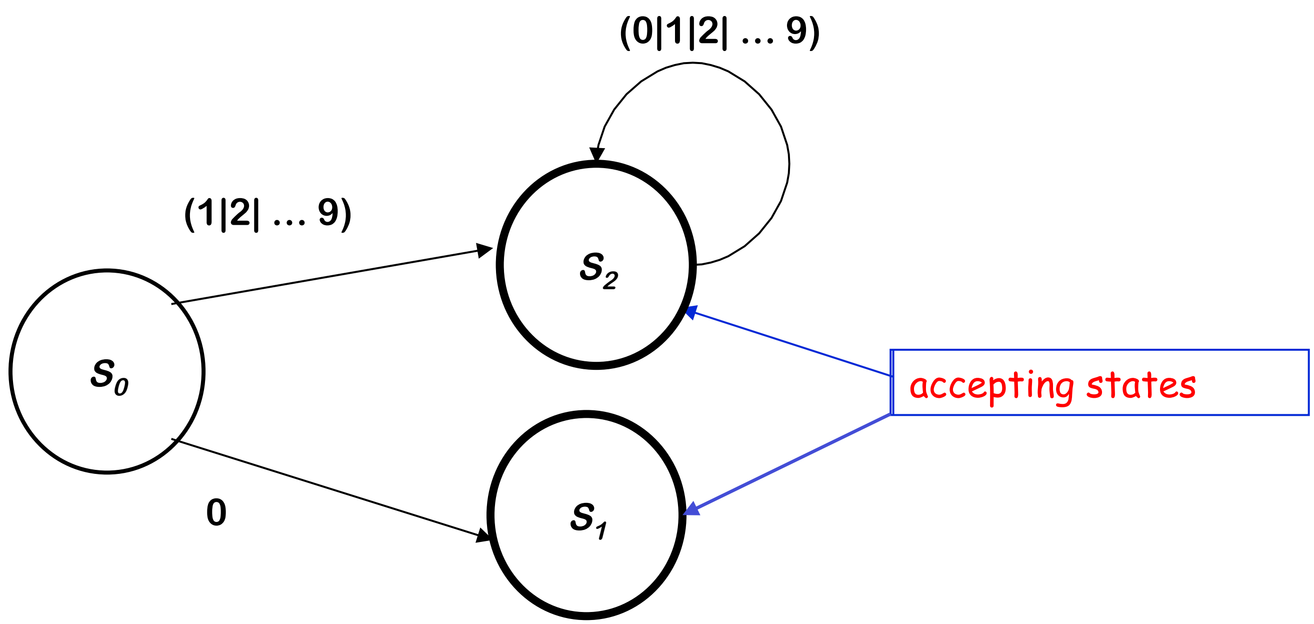
<u>Transition Diagram for *Number*</u>

Finite Automaton (FA)

An FA is a five-tuple $(S,\Sigma,\partial,s_0,S_F)$ where

- S is the set of states
- Σ is the alphabet
- ∂ a set of transition functions
  - takes a state and a character and returns new state
- s_0 is the start state
- S_F is the set of final states

Finite Automaton (FA)



Transition Diagram for *Number*