CSE P 501 – Compilers

Languages, Automata, Regular Expressions & Scanners

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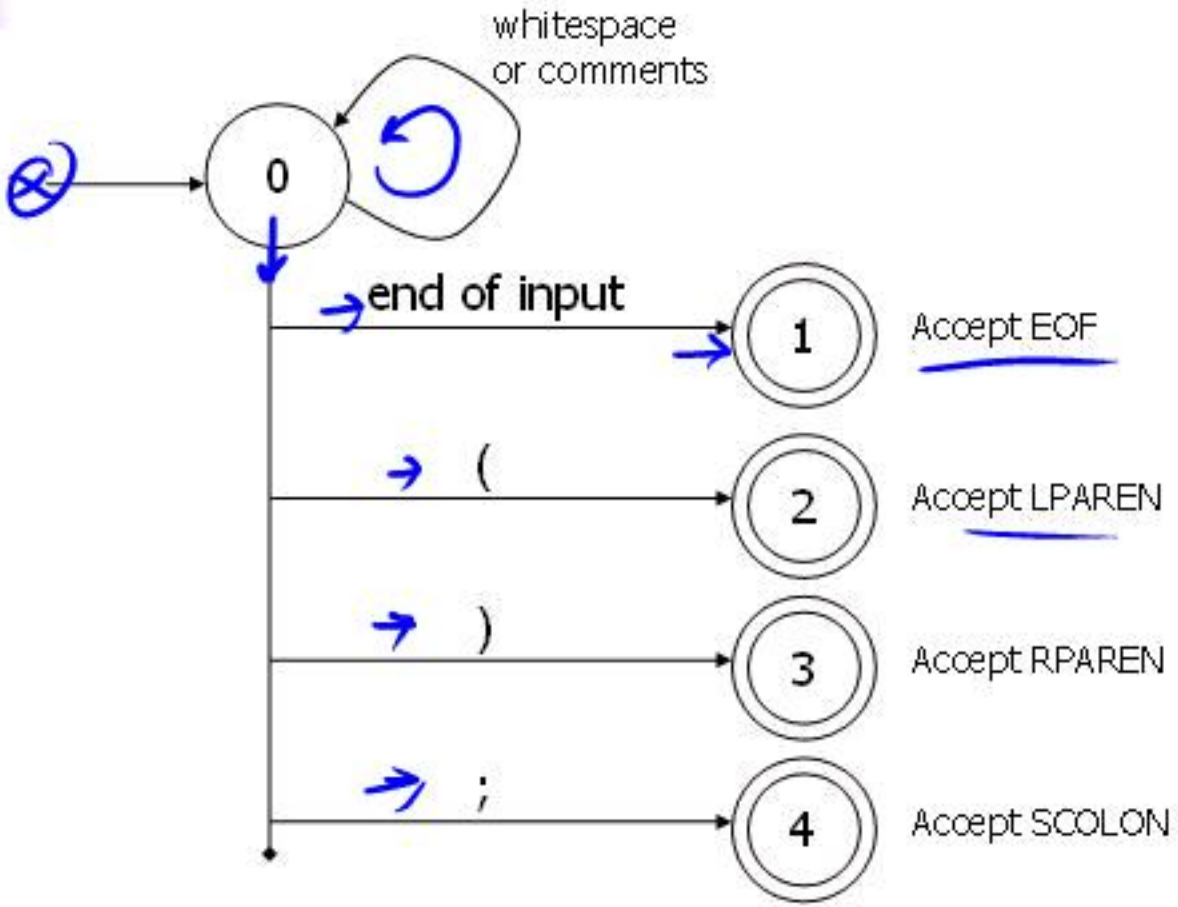
From NFA to DFA

- Subset construction
  - Construct a DFA from the NFA, where each DFA state represents a *set* of NFA states
- Key idea
  - The state of the DFA after reading some input is the set of *all* states the NFA could have reached after reading the same input
- Algorithm: example of a fixed-point computation
- If NFA has n states, DFA has at most 2^n states
  - => DFA is finite, can construct in finite # steps
- Resulting DFA may have more states than needed
  - See books for construction and minimization details

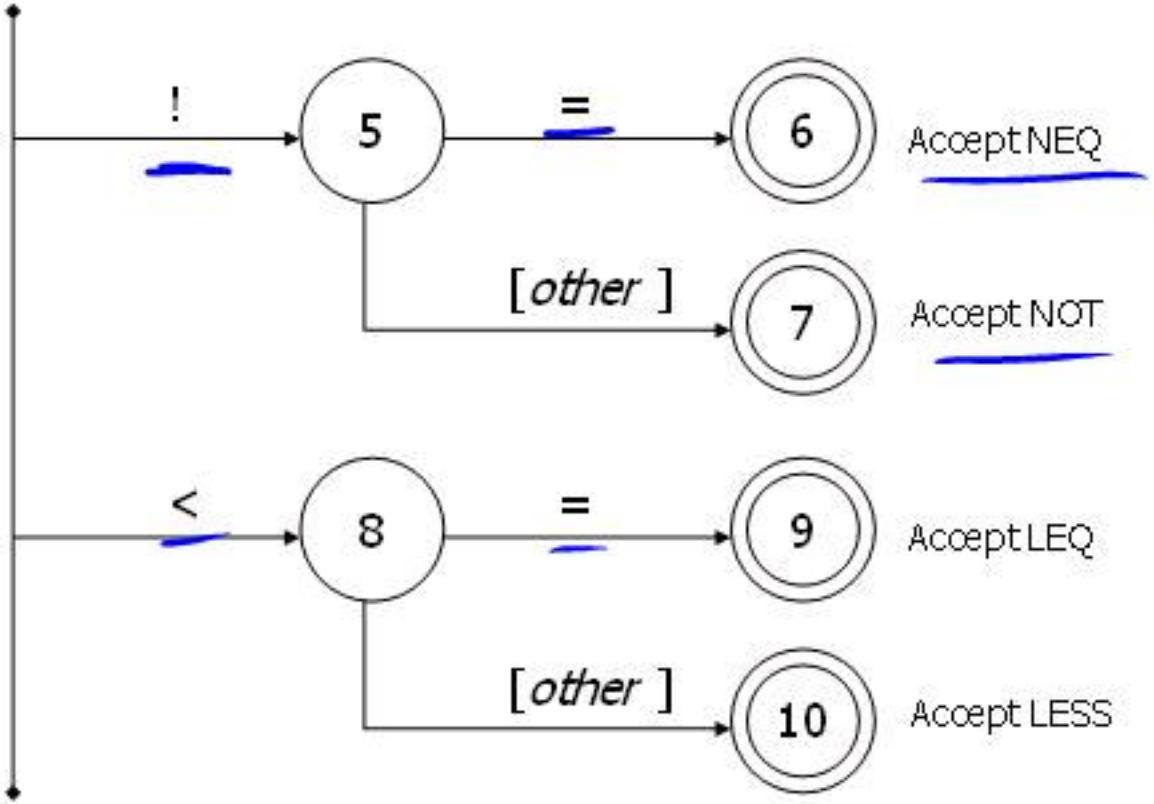
Example: DFA for hand-written scanner

- Idea: show a hand-written DFA for some typical programming language constructs
  - Then use to construct hand-written scanner
- Setting: Scanner is called whenever the parser needs a new token
  - Scanner stores current position in input
  - Starting there, use a DFA to recognize the longest possible input sequence that makes up a token and return that token
- Disclaimer: For illustration only. Course project will use scanner generator

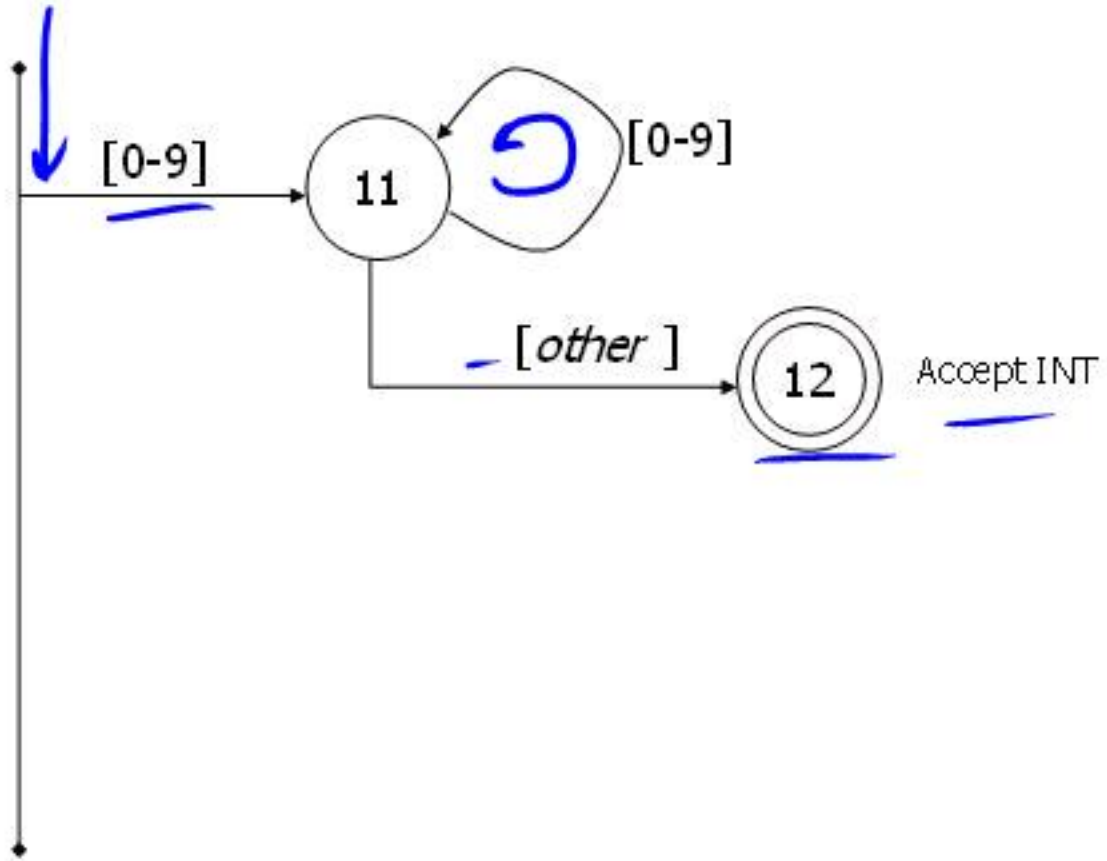
Scanner DFA Example (1)



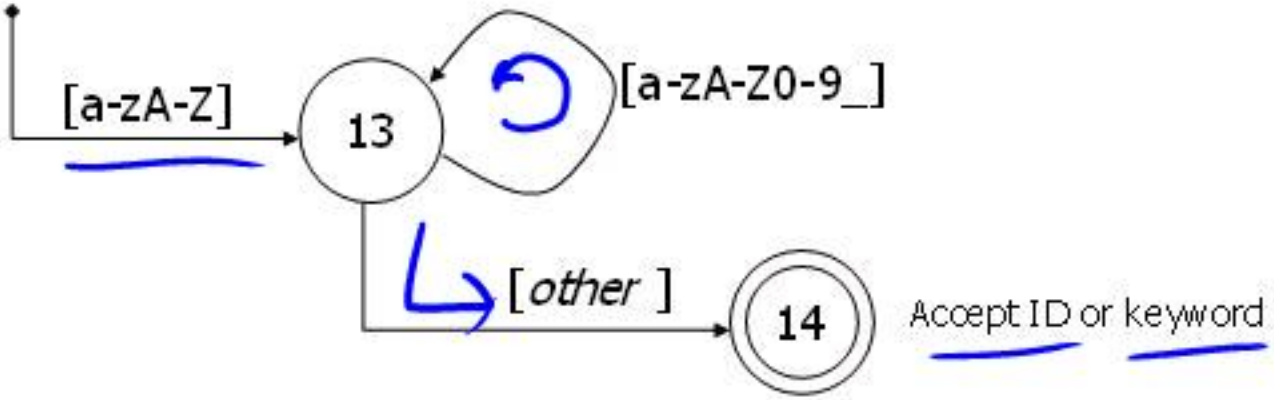
Scanner DFA Example (2)



Scanner DFA Example (3)



Scanner DFA Example (4)



- Strategies for handling identifiers vs keywords
  - Hand-written scanner: look up identifier-like things in table of keywords to classify (good application of perfect hashing)
  - Machine-generated scanner: generate DFA will appropriate transitions to recognize keywords
    - Lots 'o states, but efficient (no extra lookup step)

Implementing a Scanner by Hand – Token Representation

- A token is a simple, tagged structure

```
public class Token {
  public int kind;          // token's lexical class
  public int intVal;        // integer value if class = INT
  public String id;         // actual identifier if class = ID
    // lexical classes
  public static final int EOF = 0;     // "end of file" token
  public static final int ID  = 1;     // identifier, not keyword
  public static final int INT = 2;     // integer
  public static final int LPAREN = 4;
  public static final int SCOLN  = 5;
  public static final int WHILE  = 6;
  // etc. etc. etc. ...
```

better: use enums if you have them

Simple Scanner Example

```
// global state and methods

static char nextch;        // next unprocessed input character

// advance to next input char
void getch() { ... }

// skip whitespace and comments
void skipWhitespace() { ... }
```

Scanner getToken() method

```
// return next input token
public Token getToken() {
  Token result;

  skipWhiteSpace();

  if (no more input) {
    result = new Token(Token.EOF); return result;
  }

  switch(nextch) {
     case '(': result = new Token(Token.LPAREN); getch(); return result;
     case ')': result = new Token(Token.RPAREN); getch(); return result;
     case ';': result = new Token(Token.SCOLON); getch(); return result;

     // etc. ...
```

getToken() (2)

```
case '!': // ! or !=
          getch();
          if (nextch == '=') {
            result = new Token(Token.NEQ); getch(); return result;
          } else {
            result = new Token(Token.NOT); return result;
          }

case '<': // < or <=
          getch();
          if (nextch == '=') {
            result = new Token(Token.LEQ); getch(); return result;
          } else {
            result = new Token(Token.LESS); return result;
          }
// etc. ...
```

getToken() (3)

```
case '0': case '1': case '2': case '3': case '4':
case '5': case '6': case '7': case '8': case '9':
        // integer constant
        String num = nextch;
        getch();
        while (nextch is a digit) {
          num = num + nextch; getch();
        }
        result = new Token(Token.INT, Integer(num).intValue());
        return result;
...
```

getToken() (4)

```
case 'a': ... case 'z':
case 'A': ... case 'Z':  // id or keyword
      string s = nextch; getch();
      while (nextch is a letter, digit, or underscore) {
        s = s + nextch; getch();
      }
      if (s is a keyword) {
        result = new Token(keywordTable.getKind(s));
      } else {
        result = new Token(Token.ID, s);
      }
      return result;
```

Project Notes

- For the course project (when we get there), use a lexical analyzer generator
- Suggestion: JFlex a Java Lex-lookalike
  - Works with CUP – a Java yacc/bison implementation
  - Symbolic constant definitions for lexical classes shared between scanner/parser – usually defined in parser input file