Lexical Analysis

(Part 2)

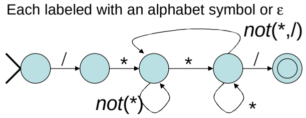
Lexical analysis is the first phase of compilation: The file is converted from ASCII to tokens. It must be fast!

Building Scanners with REs

- Convert RE specification into a **finite state automaton** (FSA) (aka FA)
- Convert FSA into a scanner implementation
  - By hand into a collection of procedures
  - Mechanically into a table-driven scanner

Finite State Automata

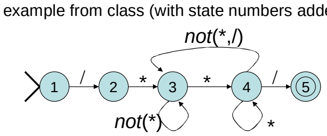
- A Finite State Automaton has
  - A set of states
    - One marked initial
    - Some marked final
  - A set of transitions from state to state
    - Each labeled with an alphabet symbol or ε



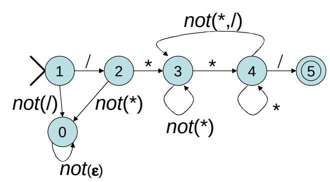
  - Operate by beginning at the start state, reading symbols and making indicated transitions
    - ***If no transition with a matching label is found, reject***
  - When input ends, accept if in final state, otherwise reject

Additional Notes

Our example from class (with state numbers added):



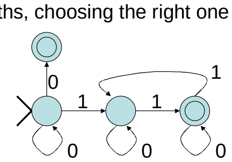
This figure represents a DFA even though it is not complete (i.e., not all state-character transitions have been drawn). The complete DFA is:



but it is very common to ignore state 0 (called the *error state*) since it is implied. The error state serves as a black hole, which doesn't let you escape.

Determinism

- FSA can be **deterministic** or **nondeterministic**
- **<u>Deterministic</u>**: always know uniquely which edge to take
  - At most 1 arc leaving a state with a given symbol
  - No ε arcs
- **<u>Nondeterministic</u>**: may need to guess or explore multiple paths, choosing the right one later



NFAs vs DFAs

- A problem:
  - REs (e.g. specifications) map easily to NFAs
  - ...
  - Can write code for DFAs easily
- How to bridge the gap?
- Can it be bridged?

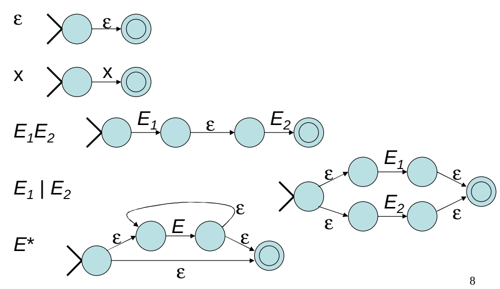
A Solution

- Cool algorithm to translate any NFA to a DFA
  - Proves that NFAs aren't any more expressive
- Plan:
  1) Convert RE to NFA
  2) Convert NFA to DFA
  3) Convert DFA to code
- Can be done by hand or fully automatically

7

RE => NFA

Construct Cases Inductively



8

NFA => DFA

- **Subset Construction**
  - Construct a DFA from the NFA, where each state in the DFA represents a *set of states from the NFA*
- **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.

9

Subset Construction Algorithm (NFA => DFA)

Given NFA with states and transitions:
- label all **NFA** states uniquely

Create start state of DFA:
- label it with the ***set of NFA states*** (e.g. $\{s_1,\ldots,s_n\}$) reachable from the start state of the **NFA** by ε transitions, i.e. w/o consuming input.
- Add this new start state to the **WorkList**.

while (WorkList is not empty) {

Remove a state S with label $\{s_1,\ldots,s_n\}$ from the **WorkList**.

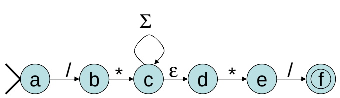
For each symbol x in the alphabet:
- Compute the set $\{t_1,\ldots t_m\}$ of **NFA** states reached from any of the **NFA** states in $\{s_1,\ldots,s_n\}$ by an x transition (followed by any number of ε transitions – a.k.a. the E-closure).
- If $\{t_1,\ldots t_m\}$ is not empty:
  - If a **DFA** state **T** labeled $\{t_1,\ldots t_m\}$ already exists, add a x transition from **S** to **T**.
  - Else create new **DFA** state **T** labeled $\{t_1,\ldots t_m\}$, add a x transition from **S** to **T**, add **T** to the **WorkList**.

}

A DFA state is final iff at least one of the NFA states in its label is final.

10

Subset Construction



11