CSE 322

Exam Reviews
Basic Concepts

• Formal Languages
  – Alphabet (\(\Sigma\))
  – String (\(\Sigma^*\))
  – Length (\(|x|\))
  – Empty String (\(\epsilon\))
  – Empty Language (\(\varnothing\))

• Language/String Operations
  – “Regular” Operations:
    • Union (\(\cup\))
    • Concatenation (\(\cdot\))
    • (Kleene) Star (\(*\))
  – Other:
    • Intersection
    • Complement
    • Reversal
    • Shuffle
    • ...
Finite Defns of Infinite Languages

- English, mathematical
- DFAs
  - States
  - Start states
  - Accept states
  - Transitions (δ function)
  - M accepts $w \in \Sigma^*$
  - M recognizes $L \subseteq \Sigma^*$

- Nondeterminism
- NFAs
  - Transitions (δ relation)
    - Missing out-edges
    - Multiple out-edges
    - ε-moves
  - N accepts $w \in \Sigma^*$
  - N recognizes $L \subseteq \Sigma^*$

- Regular Expressions
  - $\emptyset, \varepsilon, a \in \Sigma$, $\cup, \cdot, \ast, \left( \right)$

- GNFAs
Key Results, Constructions, Methods

• L is regular iff it is:
  – Recognized by a DFA
  – Recognized by a NFA
  – Recognized by a GNFA
  – Defined by a Regular Expr

Proofs:

- GNFA $\rightarrow$ Reg Expr
  \[(\text{Kleene/Floyd/Warshall: } R_{ik} R_{kk}^* R_{kj})\]
- Reg Expr $\rightarrow$ NFA
  \[(\text{join NFAs w/ } \varepsilon\text{-moves})\]
- NFA $\rightarrow$ DFA
  \[(\text{subset construction})\]
- DFA $\rightarrow$ GNFA
  \[(\text{special case})\]

• The class of regular languages is closed under:
  – Regular ops: union, concatenation, star
  – Also: intersection, complementation, (& reversal, prefix, no-prefix, …)

• NOT closed under $\subseteq$, $\supseteq$

• Also: Cross-product construction (union, …)
Applications

- “globbing”
  - lpr *.txt
- pattern-match searching:
  - grep “Ruzzo.*terrific” *.txt

- Compilers:
  - $\text{Id} ::= \text{letter} ( \text{letter|digit} )^*$
  - $\text{Int} ::= \text{digit} \text{digit}^*$
  - $\text{Float} ::= d \text{d*} . \text{d*} ( \epsilon | E \text{d d*} )$
  - (but not, e.g. expressions with nested, balanced parens, or variable names matched to declarations)

- Finite state models of circuits, control systems, network protocols, API’s, etc., etc.