CSE 322

Exam Reviews
Basic Concepts

• Formal Languages
  – Alphabet ($\Sigma$)
  – String ($\Sigma^*$)
  – Length ($|x|$)
  – Empty String ($\varepsilon$)
  – Empty Language ($\emptyset$)

• 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 (\(\delta\) function)
  - \(M\) accepts \(w \in \Sigma^*\)
  - \(M\) recognizes \(L \subseteq \Sigma^*\)

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

- Regular Expressions
  - \(\emptyset, \varepsilon, a \in \Sigma, \cup, \cdot, *, ()\)

- 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 → Reg Expr
  (Kleene/Floyd/Warshall: $R_{ik} R_{kk}^* R_{kj}$)

- Reg Expr → NFA
  (join NFAs w/ ε-moves)

- NFA → DFA
  (subset construction)

• 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:
  - `Id ::= letter ( letter|digit )*`
  - `Int ::= digit digit*`
  - `Float ::= d d* . d* ( ε | E 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.