Automatic Speech Recognition (CS753)
Lecture 3: WFSTs contd./WFSTs in Speech Recognition

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Lecture 3
Composition: Recap

- If $T_1$ transduces $x$ to $z$, and $T_2$ transduces $z$ to $y$, then $T_1 \circ T_2$ transduces $x$ to $y$

- Note: output alphabet of $T_1 \subseteq$ input alphabet of $T_2$

- E.g. If $T_1$ removes punctuation symbols from a string, and $T_2$ changes uppercase letters to lowercase letters, then $T_1 \circ T_2$ brings about both changes
Determinization and Minimization

- WFSTs constructed using various operations (or designed by hand) may have several redundancies
  - Affects the efficiency of subsequent operations
- Determinization and minimization seek to remove redundancies
  - Determinization can expand a WFST, but makes it faster to process an input string
  - Minimization results in the smallest number of states
- Will discuss WFSAs here. Extends to WFSTs.
Deterministic FSAs

- An FSA is **deterministic** if:
  - Unique start state
  - No two transitions from a state share the same label
  - No epsilon labels

Any input sequence yields a unique path (if at all)

Deterministic or non-deterministic?
Determinization

Construct an equivalent deterministic FSA

States correspond to subsets of states in the original FSA

non-deterministic FSA

equivalent deterministic FSA
Determinization: Weighted FSA

Some *Weighted*-FSAs are not determinizable! [M97]

Weight of string $ab^n c = n$ and weight of $ab^n d = 2n$

After seeing $ab^n$ an FSA can’t remember $n$

Determinization: Weighted FSA

Two WFSAs are equivalent if they associate the same weight to each input string.

non-deterministic WFSA

equivalent deterministic WFSA
Minimization

Minimization: find an equivalent deterministic FSA with the least number of states (and transitions)

Unweighted FSAs have a unique minimal FSA [Aho74]

Obtained by identifying and merging equivalent states

Minimization: Weighted FSA

Two states are equivalent only if for every input string, the outcome — weight assigned to the string, if accepted — starting from the two states are the same.

Redistribute weights before identifying equivalent states.
Minimization: Weighted FSA

Reweighting OK as long as resulting WFSA is equivalent

Can reweight using a “potential function” on states

“Weight pushing”: Reweighting using a potential function that optimally moves weights towards the start state
Minimization: Weighted FSA

After weight-pushing, can simply apply unweighted FSA minimization (treating label/weight as label)

Guaranteed to yield a minimal WFSA (under some technical conditions required for weight-pushing)