G52MAL
Machines and Their Languages
Lecture 7
Minimization of Finite Automata

Henrik Nilsson

University of Nottingham

Minimization? What and Why?

Q: Is there a unique smallest DFA for recognizing a particular regular language?

A:
- Yes! (Up to renaming of states.)
- Moreover, this minimal DFA can be found mechanically.

Why useful?

- Small improves efficiency if we want to implement a DFA.
- Unique means it is easy to check if two automata really are the same.

Applications (1)

Applying all we know after this lecture, we can for example:

- Given a regular expression E, construct the smallest possible DFA for recognizing the language:

$$minimize(D(N(E)))$$

This is in essence what tools like Lex and Flex do generate efficient scanners from declarative specifications stated in terms of regular expressions.

Applications (2)

- Given two regular expressions E and F, check if they denote the same language.

  For example, are $\mathbf{a}^*$ and $(\mathbf{a}^*)^*$ equivalent?

  One possibility:

$$minimize(D(N(E))) = minimize(D(N(F)))$$

  where $=$ is a structural comparison of DFAs.

  Not the only or necessarily the best way, but it is one way.

Testing Equivalence of States

For DFA $(Q, \Sigma, \delta, q_0, F)$, states $p, q \in Q$ are ***equivalent*** iff $\forall w \in \Sigma^* \,.\, \hat{\delta}(p, w) \in F \Leftrightarrow \hat{\delta}(q, w) \in F$

If two states are not equivalent, then they are ***distinguishable*** on at least one word w.

Note that an accepting state is always distinguishable from a non-accepting state on the empty word ϵ. To see this, assume $p \in F, q \notin F$. Then:

$$\hat{\delta}(p, \epsilon) = p \in F$$
$$\hat{\delta}(q, \epsilon) = q \notin F$$

The Table-filling Algorithm (1)

Systematic discovery of distinguishable state pairs for DFA $(Q, \Sigma, \delta, q_0, F)$:

BASIS:
For $p, q \in Q$, if

$$(p \in F \wedge q \notin F) \vee (p \notin F \wedge q \in F)$$

then (p, q) is a distiguishable state pair.

The Table-filling Algorithm (2)

INDUCTION:
For $p, q, r, s \in Q$, $a \in \Sigma$, if

$$(r, s) = (\hat{\delta}(p, a), \hat{\delta}(q, a))$$

a distinguishable state pair, then (p, q) is also a distinguishable state pair.

Theorem: If two states are ***not*** distinguishable by the table-filling algorithm, then they are ***equivalent***.