

Automata Theory - Homework II (Solutions)

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1 Problems

1. Let L be a regular language not containing λ . Argue that there exists a right-linear grammar for L , whose productions are restricted to the forms:

$$\begin{aligned} A &\rightarrow \alpha B, \text{ and} \\ A &\rightarrow \alpha \end{aligned}$$

where A and B are generic variables and α is a generic terminal.

Solution: In class, we showed that every regular language can be represented as a DFA $M = (Q, \Sigma, \delta, q_0, F)$, where the symbols should be interpreted using the standard convention. Since, L is λ -free, it must be the case that $q_0 \notin F$. We construct the following Right-Linear Grammar $G = (V, T, S, P)$ for L :

- (a) We use symbol A_i to denote state q_i . $V = \{A_i : i = 0, 1, \dots, |Q| - 1\}$.
- (b) The set of terminals T is precisely Σ .
- (c) $S = A_0$.
- (d) The productions P of G are defined as follows: For each transition, $\delta(q_i, \alpha) = q_j$, add the production $A_i \rightarrow \alpha A_j$. If q_j is also a final state, then add the production $A_i \rightarrow \alpha$.

We use induction on the number of transition steps to show that if $\delta(q_0, w) \in F$, then $A_0 \Rightarrow^* w$. Likewise, we use induction on the number of steps in a leftmost derivation to establish that if $A_0 \Rightarrow^* w$, then $\delta(q_0, w) \in F$.

(The induction proofs are straightforward exercises). \square

2. Consider the language $L = \{a^n : n \text{ is not a perfect square}\}$. Prove that L is not regular, by using the Pumping Lemma. You may not use complement properties of regular languages.

Solution: One way of showing that L is not regular is through the following argument: If L is regular, then so is L^c ; however, we showed in class that L^c is not regular and hence L cannot be regular. Since you were expressly forbidden from using the complement properties of regular languages, let us proceed to prove the non-regularity of L , using first principles.

Assume that L is regular and let $M = (Q, \Sigma, \delta, q_0, F)$ denote the unique minimal state DFA for L , where the symbols in the tuple have their usual meaning. Let p denote the number associated by the Pumping Lemma with L ; we know that $p = |Q|$. Let $G = \{a^{p^2+i} : i = 1, 2, \dots, 2p\}$; we can think of the strings in G as being indexed by their length after subtracting the offset p^2 . Using w_i to refer to the string a^{p^2+i} , we have that $|w_i| + 1 = |w_{i+1}|$.

Let $R = \{\delta(q_0, w_i) : w_i \in G\}$; we use r_i to denote $\delta(q_0, w_i)$, $w_i \in G$.

The following observations are in order:

- (i) All the states in R are final states.

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