

# Automata Theory - Homework II (Solutions)

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## 1 Problems

1. Let  $L$  be a regular language not containing  $\lambda$ . 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  $\alpha$  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  $\lambda$ -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  $\Sigma$ .
- (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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