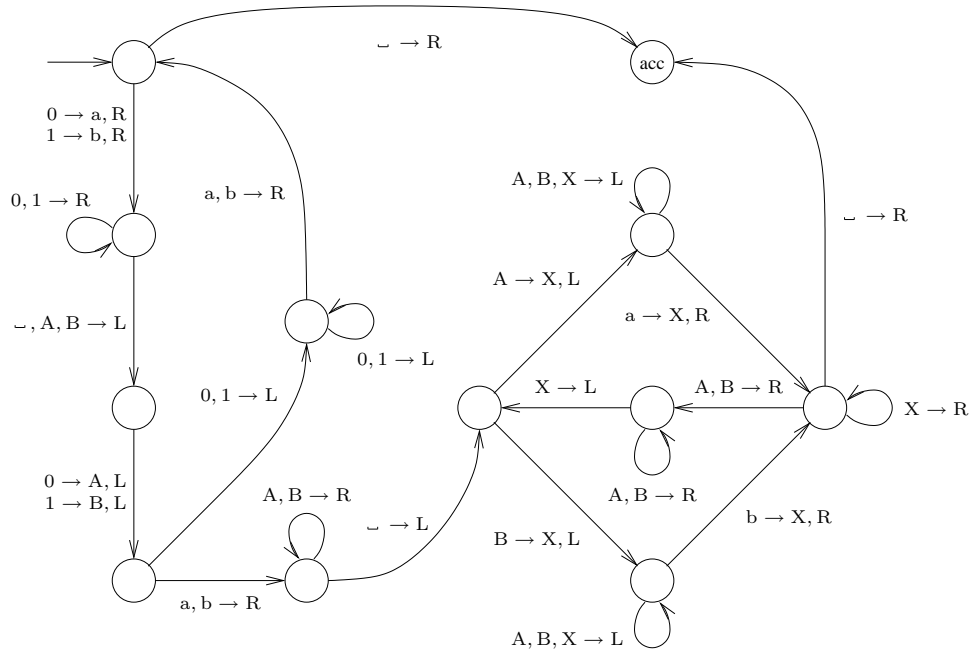


582206 Models of Computation (Autumn 2007)

Exercise 11 (27–30 October)

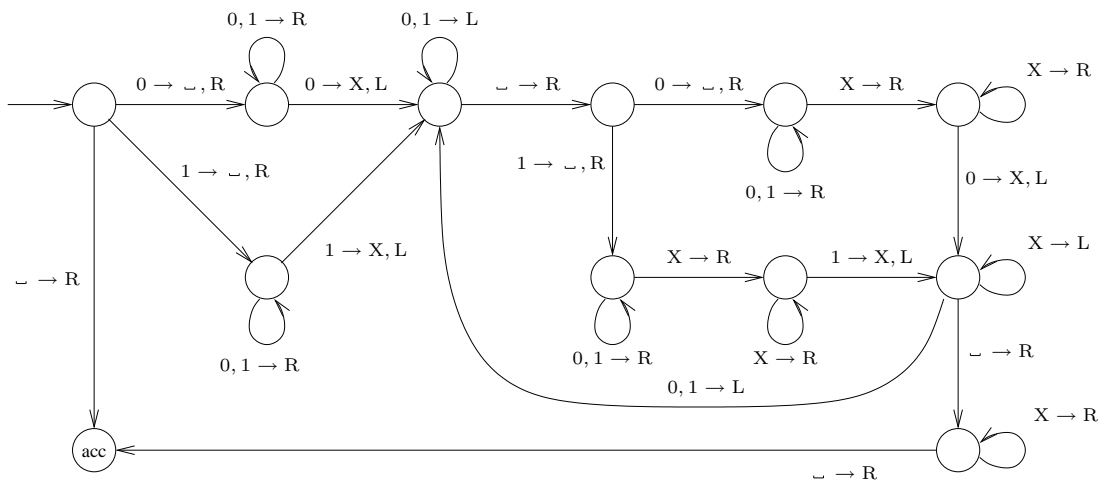
1. (Although it is not important for solving the problem, you may wish to know that both the Turing machines given in this problem recognize the language $\{ ww \mid w \in \{0, 1\}^* \}$.)

(a) Show the computation (that is, the sequence of configurations) for the deterministic Turing machine



on input 001001.

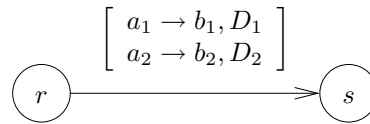
(b) Show one accepting and one rejecting computation for the nondeterministic Turing machine



on input 001001.

Problems 2–4 on the next page!

2. Give a state diagram for a Turing machine that recognizes the language $\{ a^i b^j c^i d^j \mid i, j \in \mathbb{N} \}$.
3. (a) Give a state diagram for a two-tape Turing machine that recognizes the language $\{ a^n b^n c^n \mid n \in \mathbb{N} \}$. One suitable way of representing the transition $\delta(r, a_1, a_2) = (s, b_1, b_2, D_1, D_2)$ is



- (b) Give a state diagram for a nondeterministic Turing machine that recognizes the language

$$\{ \#w_1\#w_2\#\dots\#w_n\# \mid w_i \in \{0, 1\}^* \text{ for all } i \text{ and } w_i = w_j \text{ for some } i \neq j \}$$

over the alphabet $\{0, 1, \#\}$.

4. A *queue automaton* is like a push-down automaton, except that a queue replaces the stack. Two kinds of operations can be performed on the queue:
- ENQUEUE(a) inserts the symbol a to the end of the queue
 - DEQUEUE reads and deletes the first symbol of the queue.

As with a PDA, the input can be read one symbol at a time. We assume that the end of the input is denoted by the symbol \sqcup that may not appear anywhere else in the input. The queue automaton accepts by entering a special accept state (like a Turing machine).

Show that any Turing-recognizable language can be recognized by a queue automaton. A sufficient solution to this problem is to explain, using a suitable level of pseudocode, how a Turing machine can be simulated using a queue.