#### **AMERICAN INTERNATIONAL UNIVERSITY-BANGLADESH**



#### **CSC3113: THEORY OF COMPUTATION**

Lecture: # 4

Week: # 2

Semester: Spring 2022-2023

# DETERMINISTIC FINITE AUTOMATON (DFA) REGULAR LANGUAGE

Instructor: Shakila Rahman, Lecturer,

Department of Computer Science, Faculty of Science & Technology.

Shakila.Rahman@aiub.edu

## **LECTURE OUTLINE**



- **尽** Regular Language
  - → Problem solving applying regular operation, Union.
  - **→** Design Issues.

## **LEARNING OBJECTIVE**



■ Build one machine from multiple machines using closure under union.

## **LEARNING OUTCOME**



#### **ALL OUTCOME ARE REPRESENTED WITH EXAMPLES**

- Analyze and Design new machine model from one or more machine model(s) using closure rule of regular operation (example: Union).
- In doing so, understand that, there are certain cases where DFA might not give a desired machine model.

#### REGULAR LANGUAGE CLOSED UNDER UNION



- → We will prove it by construction.
- Let  $M_1$  recognize  $A_1$ , where  $M_1$ =  $(Q_1, \Sigma, \delta_1, q_1, F_1)$ , and  $M_2$  recognize  $A_2$ , where  $M_2$ =  $(Q_2, \Sigma, \delta_2, q_2, F_2)$ .
- Construct M to recognize  $A_1 \cup A_2$ , where  $M = (Q, \Sigma, \delta, q_0, F)$ .

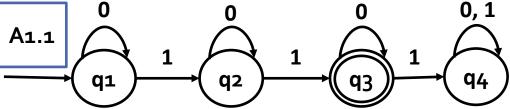
  - $\pi \Sigma = \Sigma_1 \cup \Sigma_2$ .
    - **7** But here, for simplicity, we have considered  $\Sigma_1 = \Sigma_2$  to be same.
  - - Hence  $\delta$  gets a state of M (which actually is a pair of states from  $M_1$  and  $M_2$ ), together with an input symbol, and returns M's next state.

  - **7** $F = { (r_1, r_2) : r_1 \in F_1 \text{ or } r_2 \in F_2 }$



#### Let us consider them separately

#### A1.1={w| w has exactly two 1s}



$$M_{1.1} = (Q_{1.1}, \Sigma_{1.1}, \delta_{1.1}, q_{0.1.1}, F_{1.1}),$$
where –
$$Q_{1.1} = \{q_1, q_2, q_3, q_4\},$$

$$\Sigma_{1.1} = \{0, 1\}$$

$$q_{0.1.1} = q_1,$$

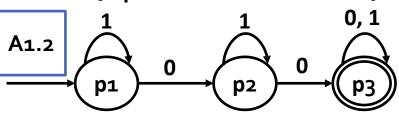
$$F_{1.1} = \{q_3\},$$

$$\delta_{1.1}$$

$$\begin{vmatrix} 0 & 1 \\ q_1 & q_2 \\ q_2 & q_3 \\ q_3 & q_3 \end{vmatrix} = q_3$$

 $q_4$ 

#### A1.2= $\{w \mid w \text{ has at least two } os\}$



 $| q_{\Delta}|$ 

 $q_4$ 

| A1={w  w has exactly two 1s or at least two 0s} for $\Sigma = \{0,1\}$ . |   |   |   |   | 9                       |                    |
|--|---|---|---|---|-------------------------|--------------------|
| $M_{1.1} = (Q_{1.1}, \Sigma_{1.1}, \omega_{0.1})$                        | $\delta_{1.1}$ , $q_{0.1.1}$ , $F_{1.1}$ ), | δ | 0 | 1 | $\Sigma = \Sigma_{1.1}$ | ) Σ <sub>1.2</sub> |

|                                     |   | _   |  |
|-------------------------------------|---|---|--|
| <sub>1.1</sub> = (C                 | $l_{1.1}$ , $l_{1.1}$   | Σ <sub>1.1</sub> , ι  | $\delta_{1.1}$ , $q_{0.1.1}$ , $F_{1.1}$ ),  |
| where                               | e –   |   |  |
| $Q_{11}$                            | $= \{ c$  | $q_1,q_2$   | $,q_3,q_4\},$  |
| $\Sigma_{1,1}$                      | $= \dot{\{}$  | 0, 1}   | , 13 / 14//  |
|                                     |   |   |  |
| <b>9</b> 0.1.1                      | _ {   | 71)<br>71 }   |  |
|                                     | 1   | 431,  |  |
| $\delta_{\!\scriptscriptstyle 1.1}$ | 0   | 1   |  |
|                                     |   | ~   | -  |
| $q_1$                               | $q_1$   | $q_2$   |  |
| $a_{-}$                             | 92  | <b>4</b> 3  |  |
| $a_{4}$                             | $a_{4}$   | $a_{\bullet}$   |  |
|                                     |   |   |  |
| <sub>1.2</sub> = (C                 | $Q_{1,2}, Q_{1,2}$  | Σ <sub>1.2</sub> , ι  | $\delta_{1,2}$ , $q_{0,1,2}$ , $F_{1,2}$ ),  |
| where                               | e –   |   |  |
| $Q_{12}$                            | $= \{ p \}$   | 1,D2,I  | $\mathcal{O}_{2}$ ,  |
| $\Sigma_{1.2}$                      | $=\{0$  | . 1}  | - 317  |
|                                     |   |   |  |
| <b>9</b> 0.1.2                      | _   | י <sub>1</sub> י  |  |
| $r_{1.2}$                           | _ \p  | 33,   |  |
| $\delta_{\!\scriptscriptstyle 1.2}$ | 0   | 1   |  |
|                                     | n   | n   | -  |
| $n_2^1$                             | $n_2$   | $p_1$   |  |
| $n_2$                               |   |   |  |
|                                     | where $Q_{1.1}$ $\Sigma_{1.1}$ $q_{0.1.1}$ $F_{1.1}$ $\delta_{1.1}$ $q_{1}$ $q_{2}$ $q_{3}$ $q_{4}$ where $Q_{1.2}$ $\Sigma_{1.2}$ $q_{0.1.2}$ $F_{1.2}$ $\delta_{1.2}$ $\rho_{1}$ $\rho_{2}$ | where $ Q_{1.1} = \{0\}$ $\sum_{1.1} = \{0\}$ $F_{1.1} = \{0\}$ $F_{1.2} = \{0\}$ | $\begin{array}{c} Q_{1.1} &= \{q_1,q_2\\ \Sigma_{1.1} &= \{0,1\}\\ q_{0.1.1} &= q_1,\\ F_{1.1} &= \{q_3\},\\ \delta_{1.1} & 0 & 1 \\ \hline q_1 & q_1 & q_2\\ q_2 & q_3 & q_4\\ q_4 & q_4 & q_4 \\ 1.2 &= \{Q_{1.2}, \Sigma_{1.2},\\ \text{where} &- \\ Q_{1.2} &= \{p_1,p_2,\\ \Sigma_{1.2} &= \{0,1\}\\ q_{0.1.2} &= p_1,\\ F_{1.2} &= \{p_3\},\\ \delta_{1.2} & 0 & 1 \\ \hline p_1 & p_2 & p_1\\ p_2 & p_3 & p_2 \\ \end{array}$ |

| δ   | 0 | 1 | <b>←</b> |
|---|---|---|----------|
| $(q_1, p_1)$ $(q_1, p_2)$ $(q_1, p_3)$ $(q_2, p_1)$ $(q_2, p_2)$ $(q_2, p_3)$ $(q_3, p_1)$ $(q_3, p_2)$ $(q_3, p_3)$ $(q_4, p_1)$ $(q_4, p_2)$ $(q_4, p_3)$ |   |   |          |

 $Q = Q_{1.1} \times Q_{1.2}$  (Tuples)

| $M_{1.1}$ = ( $Q_{1.1}$ , $\Sigma_{1.1}$ , $\delta_{1.1}$ , $q_{0.1.1}$ , $F_{1.1}$ ), where $-$   | δ            | 0         | 1 ←       | $\Sigma = \Sigma_{1.1} \cup \Sigma_{1.2}$ |
|--|--------------|-----------|-----------|---|
| $Q_{1.1} = \{q_1, q_2, q_3, q_4\},$  | $(q_1, p_1)$ | $(q_1, )$ | $(q_2, )$ |   |
| $\Sigma_{1.1}^{1.1} = \{0, 1\}$  | $(q_1, p_2)$ | $(q_1, )$ | $(q_2, )$ |   |
| $q_{0.1.1} = q_{1},$   | $(q_1,p_3)$  | $(q_1, )$ | $(q_2, )$ |   |
| $F_{1.1}^{0.111} = \{q_3\},$   | $(q_2, p_1)$ | $(q_2, )$ | $(q_3, )$ |   |
| $\delta_{1.1}$ 0 1   | $(q_2, p_2)$ | $(q_2, )$ | $(q_3, )$ |   |
|  | $(q_2, p_3)$ | $(q_2, )$ | $(q_3, )$ |   |
| $egin{array}{c cccc} q_1 & q_1 & q_2 \ q_2 & q_3 & q_3 \ q_3 & q_4 & q_4 \ q_4 & q_4 & q_4 \end{array}$  | $(q_3, p_1)$ | $(q_3, )$ | $(q_4, )$ |   |
| $q_2  q_2  q_3  q_3  q_4  q_5  q_6  q_8  q_8 $ | $(q_3, p_2)$ | $(q_3, )$ | $(q_4, )$ |   |
| $egin{array}{c cccc} q_3 & q_3 & q_4 \ q_4 & q_4 \end{array}$  | $(q_3, p_3)$ | $(q_3, )$ | $(q_4, )$ |   |
| · 1 · · · · · · · · · · · · · · · · · ·  | $(q_4, p_1)$ | $(q_4, )$ | $(q_4, )$ |   |
| $M_{1.2}$ = ( $Q_{1.2}$ , $\Sigma_{1.2}$ , $\delta_{1.2}$ , $q_{0.1.2}$ , $F_{1.2}$ ), where –   | $(q_4, p_2)$ | $(q_4, )$ | $(q_4, )$ |   |
|  | $(q_4, p_3)$ | $(q_4, )$ | $(q_4, )$ |   |
| $Q_{1.2} = \{p_1, p_2, p_3\},\ \Sigma_{1.2} = \{0, 1\}$  | <u> </u>     |           |           |   |
| -1.2 ( <del>-</del> ) -)   | •            |           |           |   |

 $Q = Q_{1.1} \times Q_{1.2}$ 

Fill up the tuples in the table from the transition tables  $\delta_{1.1}$  of machine  $M_{1.1}$ .

 $q_{0.1.2} = p_1,$  $F_{1.2} = \{p_3\},$ 

|  | ·   |                           |  |
|--|---|---------------------------|--|
| $M_{1.1}$ = ( $Q_{1.1}$ , $\Sigma_{1.1}$ , $\delta_{1.1}$ , $q_{0.1.1}$ , $F_{1.1}$ ), where – | $\delta$                                    | 0                         | $1 \qquad \longleftarrow \qquad \Sigma = \Sigma_{1.1} \cup \Sigma_{1.2}$ |
| $Q_{1,1} = \{q_1, q_2, q_3, q_4\},$  | $(q_1, p_1)$                                | $(q_1, p_2)$              | $(q_2, p_1)$   |
| $\Sigma_{1.1} = \{0, 1\}$  | $(q_1, p_2)$                                | $(q_1, p_3)$              | $(q_2, p_2)$   |
| $q_{0.1.1} = q_{1}$  | $(q_1, p_3)$                                | $(q_1, p_3)$              | $(q_2, p_3)$   |
| $F_{1.1} = \{q_3\},$   | $(q_{_{2}},p_{_{1}}) \ (q_{_{2}},p_{_{2}})$ | $(q_2, p_2) \ (q_2, p_3)$ | $(q_3, p_1)  (q_3, p_2)$   |
| $\delta_{1.1}$ 0 1   | $(q_2, p_2)$<br>$(q_2, p_3)$                | $(q_2, p_3)$ $(q_2, p_3)$ | $(q_3, p_3)$   |
| $egin{array}{c cccc} q_1 & q_1 & q_2 \ q_2 & q_3 \ \end{array}$                                | $(q_3, p_1)$                                | $(q_3, p_2)$              | $(q_4, p_1)$   |
| $q_2 q_2 q_3$  | $(q_3, p_2)$                                | $(q_3, p_3)$              | $(q_4, p_2)$   |
| $egin{array}{c cccc} q_3^- & q_3^- & q_4^- \ q_4^- & q_4^- & q_4^- \end{array}$                | $(q_3, p_3)$                                | $(q_3, p_3)$              | $(q_4, p_3)$   |
| · ·  | $(q_4, p_1)$                                | $(q_4, p_2)$              | $(q_4, p_1)$   |
| $M_{1.2}$ = ( $Q_{1.2}$ , $\Sigma_{1.2}$ , $\delta_{1.2}$ , $q_{0.1.2}$ , $F_{1.2}$ ), where – | $(q_4, p_2)$                                | $(q_4, p_3)$              | $(q_4, p_2)$   |
| $Q_{1.2} = \{p_1, p_2, p_3\},$   | $(q_4, p_3)$                                | $(q_4, p_3)$              | $(q_4, p_3)$   |
| $\Sigma_{1.2}^{1.2} = \{0, 1\}$  |   |                           |  |
| $q_{0.1.2} = p_1,$   | $Q = Q_{1.1}$                               | $\times Q_{12}$           |  |
| $F_{1.2} = \{p_3\},$   | 1.1   | 1.2                       |  |

Fill up the tuples in the table from the transition tables  $\delta_{1,2}$  of machine  $M_{1,2}$ .



| $M_{1.1}$ = ( $Q_{1.1}$ , $\Sigma_{1.1}$ , $\delta_{1.1}$ , $q_{0.1.1}$ , $F_{1.1}$ ), where –   | $\delta$                 | 0                         | 1 ← Σ                        |
|--|--------------------------|---------------------------|------------------------------|
| $Q_{1,1} = \{q_1, q_2, q_3, q_4\}, \longrightarrow$  | $(q_1,p_1)$              | $(q_1, p_2)$              | $(q_2, p_1)$                 |
| $\Sigma_{1.1} = \{0, 1\}$  | $(q_1, p_2)$             | $(q_1, p_3)$              | $(q_2, p_2)$                 |
| $q_{0,1,1}=q_1,$   | $(q_1, p_3)$             | $(q_1, p_3)$              | $(q_2, p_3)$                 |
| $F_{1.1}^{(1)} = \{q_3\},$   | $(q_2, p_1)$             | $(q_2, p_2)$              | $(q_3, p_1)$                 |
| $\delta_{1.1} \mid 0 \mid 1$   | $(q_2, p_2)$             | $(q_2, p_3)$              | $(q_3, p_2)$                 |
|  | $(q_2, p_3)$             | $(q_2, p_3)$              | $(q_3, p_3)$                 |
|  | $(q_3, p_1)$             | $(q_3, p_2)$              | $(q_4, p_1) \ (q_4, p_2)$    |
| $q_3 \mid q_3 \mid q_4 \qquad \qquad$   | $(q_3, p_2)  (q_3, p_3)$ | $(q_3, p_3) \ (q_3, p_3)$ | $(q_4, p_2)$<br>$(q_4, p_3)$ |
| $q_4 \mid q_4 $ | $(q_4, p_1)$             | $(q_4, p_2)$              | $(q_4, p_1)$                 |
| $M_{1.2} = (Q_{1.2}, \Sigma_{1.2}, \delta_{1.2}, q_{0.1.2}, F_{1.2}),$   | $(q_4, p_1)$             | $(q_4, p_2)$              | $(q_4, p_2)$                 |
| where –  | $(q_4, p_3)$             | $(q_4, p_3)$              | $(q_4, p_3)$                 |
| $Q_{1.2} = \{p_1, p_2, p_3\},$   | <b>A</b>                 | (14)1.31                  |                              |
| $\Sigma_{1.2}^{1.2} = \{0, 1\}$  |                          |                           |                              |
| $q_{0.1.2} = p_1,$   | Q                        |                           |                              |
| $F_{1,2} = \{p_3\},$   |                          |                           |                              |

$$\begin{array}{c|cccc} \delta_{1.2} & 0 & 1 \\ \hline \rho_1 & \rho_2 & \rho_1 \\ \rho_2 & \rho_3 & \rho_2 \\ \rho_3 & \rho_3 & \rho_3 \end{array}$$

Mark the start state from the start states  $q_{0.1.1}$  and  $q_{0.1.2}$  of the two machines  $M_{1.1}$  and  $M_{1.2}$ .

Mark the final states from the set of final states  $F_{1.1}$  and  $F_{1.2}$  of the two machines  $M_{1.1}$  and  $M_{1.2}$ .



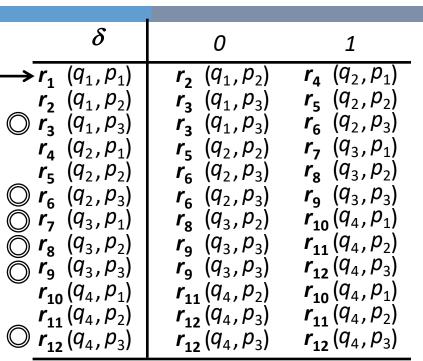
#### [optional]

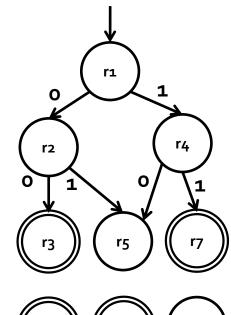
Rename each state (tuples) for the 1<sup>st</sup> column
Put these names against each state for each input
column according to the 1<sup>st</sup> column



| <b>1.</b> D | raw  | state  | diagra | m by  |
|-------------|------|--------|--------|-------|
| level       | , st | arting | with   | start |
| state       |      |        |        | _     |

- **2.** Mark all the current level states (green) in the first column & the transitions states (orange) in 2<sup>nd</sup> & 3<sup>rd</sup> column.
- **3.** Get the *next level* states (orange) from  $2^{nd}$  &  $3^{rd}$  column & draw. Mark (orange) all next level states in the whole table.
- 4. Draw the transitions.
- 5. Now, current level complete (green to red) and next level becomes current level (orange to green).
- **6.** Repeat from step 2 until all states are **red**.





#### **GREEN: State Processing**

 $r_3 r_5 r_7$ 

**ORANGE: State Appeared** 

**RED: State Processing Done** 

 $r_1 r_2 r_4$ 



| <b>1.</b> D | raw  | state  | diagra | m by  |
|-------------|------|--------|--------|-------|
| level       | , st | arting | with   | start |
| state       |      |        |        | _     |

- **2.** Mark all the current level states (green) in the first column & the transitions states (orange) in  $2^{nd}$  &  $3^{rd}$  column.
- **3.** Get the *next level* states (orange) from  $2^{nd}$  &  $3^{rd}$  column & draw. Mark (orange) all next level states in the whole table.
- 4. Draw the transitions.
- 5. Now, current level complete (green to red) and next level becomes current level (orange to green).
- **6.** Repeat from step 2 until all states are red.

| $\delta$                           | 0                      | 1                      |
|------------------------------------|------------------------|------------------------|
| $\rightarrow r_1 (q_1, p_1)$       | $r_2 (q_1, p_2)$       | $r_4 (q_2, p_1)$       |
| $r_2 (q_1, p_2)$                   | $r_3 (q_1, p_3)$       | $r_{5} (q_{2}, p_{2})$ |
| $\bigcirc r_3^- (q_1, p_3)$        | $r_3 (q_1, p_3)$       | $r_6 (q_2, p_3)$       |
| $r_4 (q_2, p_1)$                   | $r_{5} (q_{2}, p_{2})$ | $r_7 (q_3, p_1)$       |
| $r_{5} (q_{2}, p_{2})$             | $r_6 (q_2, p_3)$       | $r_8 (q_3, p_2)$       |
| $\bigcirc$ $r_6$ $(q_2, p_3)$      | $r_6 (q_2, p_3)$       | $r_9 (q_3, p_3)$       |
| $\bigcirc \mathbf{r_7} (q_3, p_1)$ | $r_8 (q_3, p_2)$       | $r_{10}(q_4,p_1)$      |
| $\bigcirc$ $r_8 (q_3, p_2)$        | $r_9 (q_3, p_3)$       | $r_{11}(q_4, p_2)$     |
| $\bigcirc$ $r_9$ $(q_3, p_3)$      | $r_9 (q_3, p_3)$       | $r_{12}(q_4, p_3)$     |
| $r_{10}(q_4, p_1)$                 | $r_{11}(q_4, p_2)$     | $r_{10}(q_4,p_1)$      |
| $r_{11}(q_4, p_2)$                 | $r_{12}(q_4, p_3)$     | $r_{11}(q_4, p_2)$     |
| $\bigcirc r_{12}(q_4, p_3)$        | $r_{12}(q_4, p_3)$     | $r_{12}(q_4, p_3)$     |

**GREEN: State Processing** 

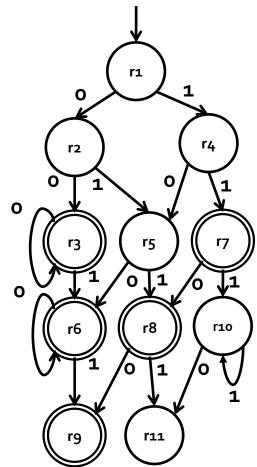
r<sub>6</sub> r<sub>8</sub> r<sub>10</sub>

**ORANGE: State Appeared** 

r<sub>9</sub> r<sub>11</sub>

**RED: State Processing Done** 

 $r_1 r_2 r_4$ 



- **1.** Draw state diagram by level, starting with start state.
- **2.** Mark all the current level states (green) in the first column & the transitions states (orange) in 2<sup>nd</sup> & 3<sup>rd</sup> column.
- **3.** Get the *next level* states (orange) from  $2^{nd}$  &  $3^{rd}$  column & draw. Mark (orange) all next level states in the whole table.
- 4. Draw the transitions.
- 5. Now, current level complete (green to red) and next level becomes current level (orange to green).
- **6.** Repeat from step 2 until all states are red.

| $\delta$   | 0  | 1  |
|--|--|--|
| $ \begin{array}{c}                                     $                                     | $r_2 (q_1, p_2)$ $r_3 (q_1, p_3)$ $r_3 (q_1, p_3)$   | $r_4 (q_2, p_1)$ $r_5 (q_2, p_2)$ $r_6 (q_2, p_3)$   |
| $r_4 (q_2, p_1)$ $r_5 (q_2, p_2)$ $r_6 (q_2, p_3)$   | $r_5 (q_2, p_2)$<br>$r_6 (q_2, p_3)$<br>$r_6 (q_2, p_3)$                                     | $r_7 (q_3, p_1)$ $r_8 (q_3, p_2)$ $r_9 (q_3, p_3)$   |
| $ \bigcirc \mathbf{r_7} (q_3, p_1) \\ \bigcirc \mathbf{r_8} (q_3, p_2) $                     | $r_8 (q_3, p_2)$<br>$r_9 (q_3, p_3)$   | $r_{10}(q_4, p_1)$<br>$r_{11}(q_4, p_2)$   |
| $ \bigcirc \mathbf{r_9} (q_3, p_3)  \mathbf{r_{10}} (q_4, p_1)  \mathbf{r_{11}} (q_4, p_2) $ | $egin{aligned} r_9 & (q_3, p_3) \\ r_{11} & (q_4, p_2) \\ r_{12} & (q_4, p_3) \end{aligned}$ | $egin{aligned} m{r_{12}} & (q_4, p_3) \\ m{r_{10}} & (q_4, p_1) \\ m{r_{11}} & (q_4, p_2) \end{aligned}$ |
| $\bigcirc \underline{\mathbf{r_{12}}}(q_4,p_3)$  | $r_{12}(q_4, p_3)$   | $r_{12}(q_4, p_3)$   |

**GREEN: State Processing** 

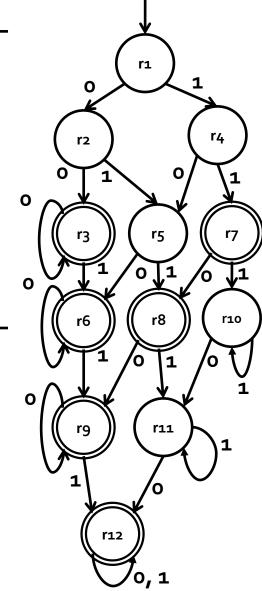
**r**<sub>12</sub>

**ORANGE: State Appeared** 

r<sub>12</sub>

**RED: State Processing Done** 

 $r_1 r_2 r_3 r_4 r_5 r_6 r_7 r_8 r_9$  $r_{10} r_{11} r_{12}$ 

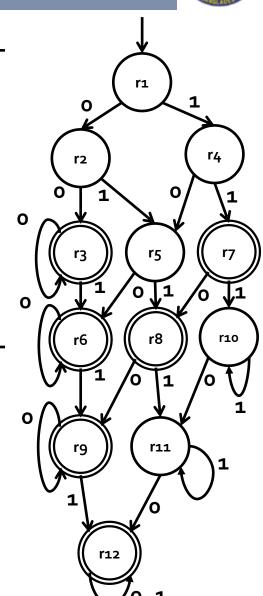




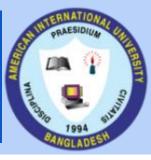
| $\delta_{1.1}$ ), $\delta$                       | 0  | 1  |  |
|--|--|--|--|
| $\longrightarrow \overline{r_1 (q_1, p_1)}$      | $r_2 (q_1, p_2)$   | $r_4 (q_2, p_1)$   |  |
| $r_2 (q_1, p_2)$ $r_2 (q_1, p_3)$                | $r_3 (q_1, p_3)$<br>$r_2 (q_1, p_3)$                     | $\mathbf{r}_{5} (q_{2}, p_{2})$<br>$\mathbf{r}_{6} (q_{2}, p_{3})$ |  |
| $r_4 (q_2, p_1)$                                 | $r_{5} (q_{2}, p_{2})$                                   | $r_7 (q_3, p_1)$   | ,  |
|  |  |  | (  |
| $\bigcirc \mathbf{r_7} (q_3, p_1)$               | $r_8 (q_3, p_2)$   | $r_{10}(q_4, p_1)$   | 0 0  |
| $\bigcirc \mathbf{r_8} (q_3, p_2)$               | $r_9 (q_3, p_3)$   | $r_{11}(q_4, p_2)$   |  |
| $r_{10}(q_4, p_1)$                               | $r_{9} (q_{3}, p_{3})$<br>$r_{11}(q_{4}, p_{2})$         | $r_{10}(q_4, p_3)$<br>$r_{10}(q_4, p_1)$                           | ( "  |
| $(q_{1.2}),  \mathbf{r}_{11}(q_4, p_2)$          | $r_{12}(q_4, p_3)$                                       | $r_{11}(q_4, p_2)$   | °C   |
| $\bigcirc \underline{\mathbf{r_{12}}(q_4, p_3)}$ | $r_{12}(q_4, p_3)$                                       | $r_{12}(q_4, p_3)$   |  |
|  |  |  |  |
|  |  |  | 0  |
|  | $ \begin{array}{c}                                     $ | $\begin{array}{c ccccccccccccccccccccccccccccccccccc$              | $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$ |

#### $\delta_{1,2} \mid 0 \mid 1$ Final Answer

- → Transition table with start and final states marked
- → State Diagram



## REFERENCES



Introduction to Theory of Computation, Sipser, (3<sup>rd</sup> ed), Regular Language.