

CMSC 330: Organization of Programming Languages

Examples of REs & Finite Automata

Describing Regular Expressions

- a) $0(0|1)^*0$
 - All strings beginning and ending in 0
- b) $((\epsilon|0)1^*)^*$
 - All strings
- c) $(0|1)^*0(0|1)(0|1)$
 - All strings with 0 as third digit from right

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Creating Regular Expressions

For all strings of 0's and 1's that...

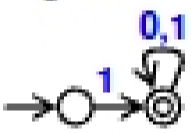
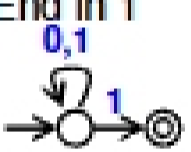
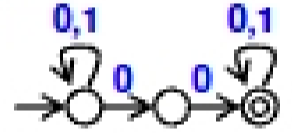
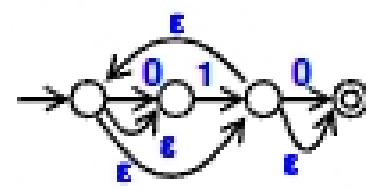
- a) Begin in 1
 - $1(0|1)^*$
- b) End in 1
 - $(0|1)^*1$
- c) Contains 00
 - $(0|1)^*00(0|1)^*$
- d) Do not contain 00
 - $(0|1)^*(\epsilon|0)$

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Creating NFA

For all strings of 0's and 1's that...

- a) Begin in 1
 
- b) End in 1
 
- c) Contains 00
 
- d) Do not contain 00
 

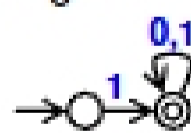
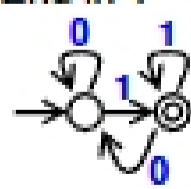
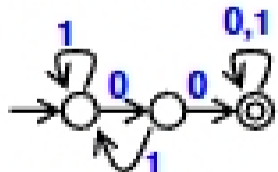
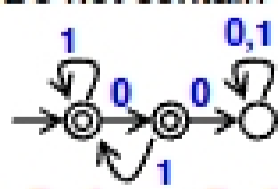
Based on regular expression

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Creating DFA

For all strings of 0's and 1's that...

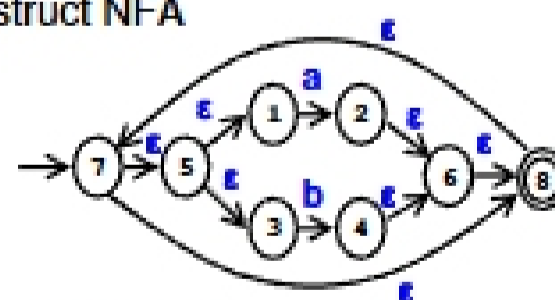
- a) Begin in 1
 
 - b) End in 1
 
 - c) Contains 00
 
 - d) Do not contain 00
 
- Swap final / non-final states!

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For RE $(a | b)^*$

a) Construct NFA



b) Accept ababbab

7,5,1,2,6,8,7,5,3,4,6,8,7,5,1,2,6,8,7,5,3,4,6,8,7,5,3,4,6,8,7,5,1,2,6,8,7,5,3,4,6,8 accept

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For RE $(a | b)^*$

c) Reduce NFA to DFA

- Start = ϵ -closure(7) = {7,5,1,3,8}
- $R = \{\{7,5,1,3,8\}\}$
- $r \in R = \{7,5,1,3,8\}$ // mark DFA state
- move ({7,5,1,3,8}, a) = {2}
 - $e = \epsilon$ -closure({2}) = {2,6,8,7,5,1,3} // new DFA state
 - $R = R \cup \{2,6,8,7,5,1,3\}$ // add to R
 - $\delta = \delta \cup (\{7,5,1,3,8\}, a, \{2,6,8,7,5,1,3\})$
- move ({7,5,1,3,8}, b) = {4}
 - $e = \epsilon$ -closure({4}) = {4,6,8,7,5,1,3} // new DFA state
 - $R = R \cup \{4,6,8,7,5,1,3\}$ // add to R
 - $\delta = \delta \cup (\{7,5,1,3,8\}, b, \{4,6,8,7,5,1,3\})$

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For RE $(a | b)^*$

- $R = \{\{7,5,1,3,8\}, \{2,6,8,7,5,1,3\}, \{4,6,8,7,5,1,3\}\}$
- $r \in R = \{2,6,8,7,5,1,3\}$ // mark DFA state
- move ({2,6,8,7,5,1,3}, a) = {2}
 - $e = \epsilon$ -closure({2}) = {2,6,8,7,5,1,3} // existing DFA state
 - $\delta = \delta \cup (\{2,6,8,7,5,1,3\}, a, \{2,6,8,7,5,1,3\})$
- move ({2,6,8,7,5,1,3}, b) = {4}
 - $e = \epsilon$ -closure({4}) = {4,6,8,7,5,1,3} // existing DFA state
 - $\delta = \delta \cup (\{2,6,8,7,5,1,3\}, b, \{4,6,8,7,5,1,3\})$

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For RE $(a | b)^*$

- $R = \{\{7,5,1,3,8\}, \{2,6,8,7,5,1,3\}, \{4,6,8,7,5,1,3\}\}$
- $r \in R = \{4,6,8,7,5,1,3\}$ // mark DFA state
- move ({4,6,8,7,5,1,3}, a) = {2}
 - $e = \epsilon$ -closure({2}) = {2,6,8,7,5,1,3} // existing DFA state
 - $\delta = \delta \cup (\{4,6,8,7,5,1,3\}, a, \{2,6,8,7,5,1,3\})$
- move ({4,6,8,7,5,1,3}, b) = {4}
 - $e = \epsilon$ -closure({4}) = {4,6,8,7,5,1,3} // existing DFA state
 - $\delta = \delta \cup (\{4,6,8,7,5,1,3\}, b, \{4,6,8,7,5,1,3\})$
- $R = \{\{7,5,1,3,8\}, \{2,6,8,7,5,1,3\}, \{4,6,8,7,5,1,3\}\}$
 - No more unmarked states to process
- $F_d = \{\{7,5,1,3,8\}, \{2,6,8,7,5,1,3\}, \{4,6,8,7,5,1,3\}\}$
 - Since $\emptyset \in F_d$

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For RE $(a | b)^*$

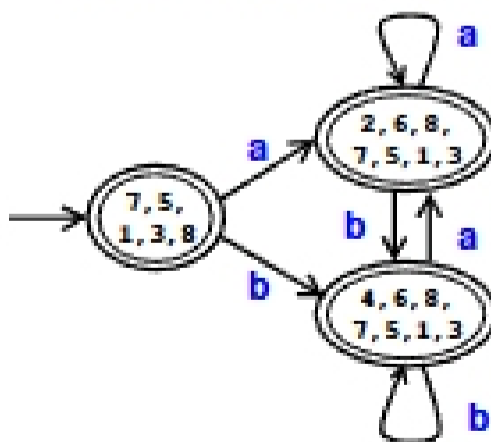
- Resulting DFA
 - $\Sigma = \{a,b\}$
 - $R = \{\{7,5,1,3,8\}, \{2,6,8,7,5,1,3\}, \{4,6,8,7,5,1,3\}\}$
 - $r_0 = \{7,5,1,3,8\}$
 - $F_d = \{\{7,5,1,3,8\}, \{2,6,8,7,5,1,3\}, \{4,6,8,7,5,1,3\}\}$
 - $\delta = \{ (\{7,5,1,3,8\}, a, \{2,6,8,7,5,1,3\}), (\{7,5,1,3,8\}, b, \{4,6,8,7,5,1,3\}), (\{2,6,8,7,5,1,3\}, a, \{2,6,8,7,5,1,3\}), (\{2,6,8,7,5,1,3\}, b, \{4,6,8,7,5,1,3\}), (\{4,6,8,7,5,1,3\}, a, \{2,6,8,7,5,1,3\}), (\{4,6,8,7,5,1,3\}, b, \{4,6,8,7,5,1,3\}) \}$

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For RE $(a | b)^*$

- NFA to DFA reduction pictorial



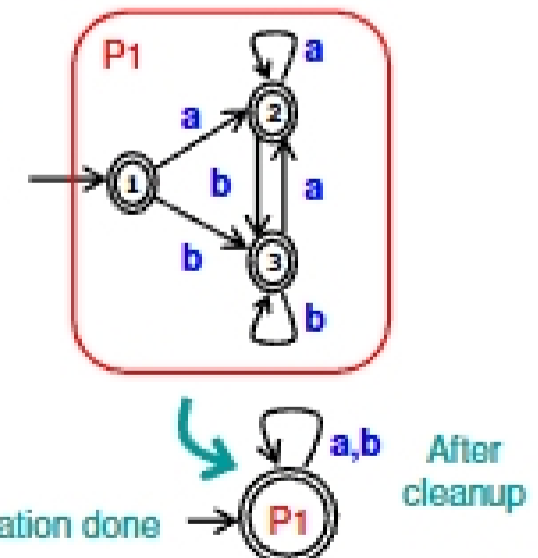
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For RE $(a | b)^*$

d) Minimize DFA

- Initial partitions
 - Accept - {1,2,3} - P1
 - Reject - \emptyset
 - Split partition?
 - move(1,a) - P1
 - move(2,a) - P1
 - move(3,a) - P1
 - move(1,b) - P1
 - move(2,b) - P1
 - move(3,b) - P1
- Not required, minimization done

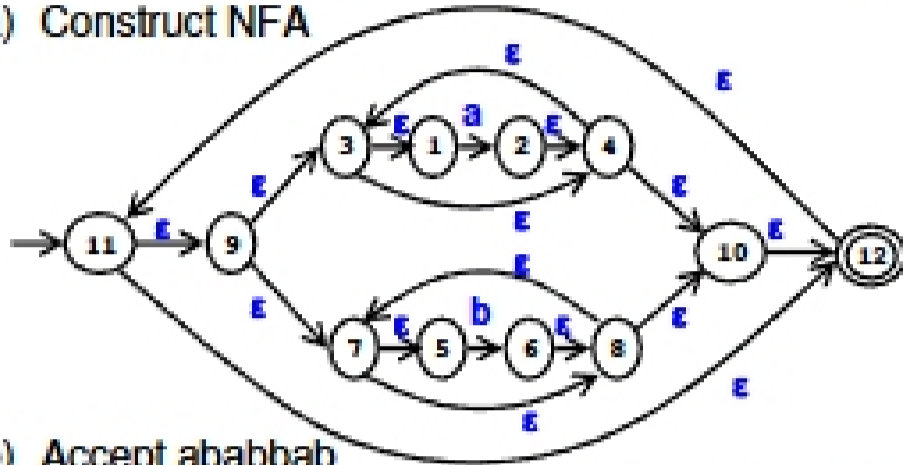


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For RE $(a^* | b^*)^*$

a) Construct NFA



b) Accept ababbab

11,9,3,1,2,4,10,12,11,9,7,5,6,8,10,12,11,9,3,1,2,4,10,12...

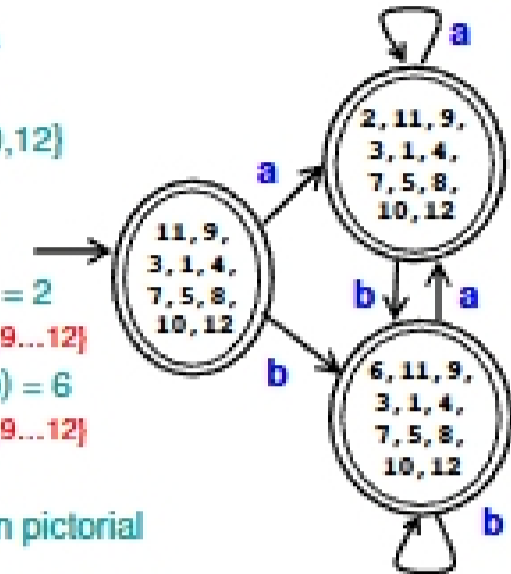
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For RE $(a^* | b^*)^*$

c) Reduce NFA to DFA

- Start = ϵ -closure(1)
- = {11,9,3,1,4,7,5,8,10,12}
- $R = \{\{11,9...12\}\}$
- $r \in R = \{11,9...12\}$
- move ($\{11,9...12\}, a$) = 2
 - ϵ -closure($\{2\}$) = {2,11,9...12}
- move ($\{11,9...12\}, b$) = 6
 - ϵ -closure($\{6\}$) = {6,11,9...12}
- ...
- NFA to DFA reduction pictorial



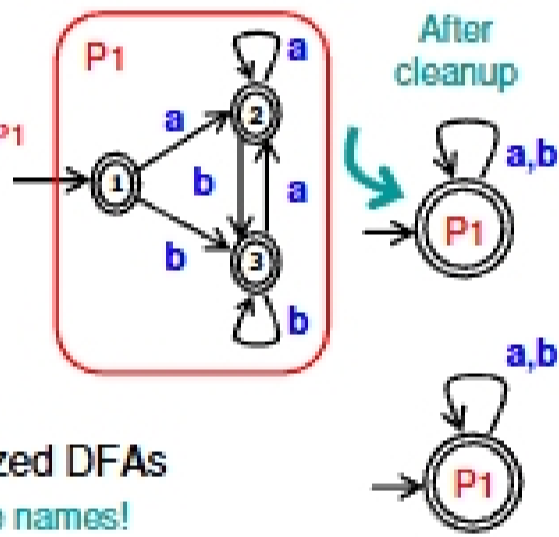
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For RE $(a^* | b^*)^*$

d) Minimize DFA

- Initial partitions
 - Accept - {1,2,3} - P1
 - Reject - \emptyset
- Split partition?
 - move(1,a) - P1
 - ...
- Not required, minimization done



e) Compare 2 minimized DFAs

- Identical up to state names!

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