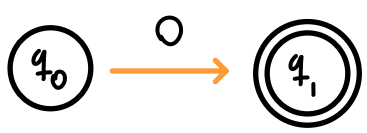
ER de los enteros → $0 + (1-9)(0-9)^* + -(1-9)(0-9)^*$

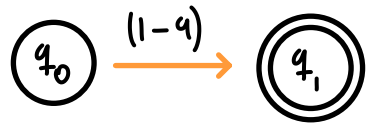
(1) ER → AFNε

1. Proceso a mano

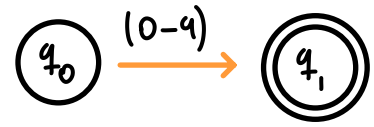
① '0'



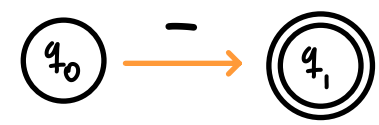
② (1-9)



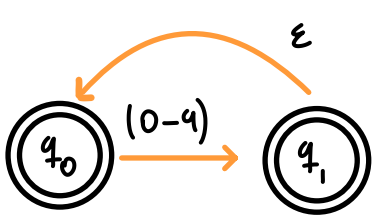
③ (0-9)



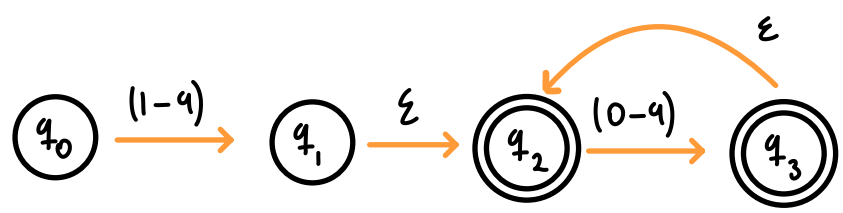
④ –



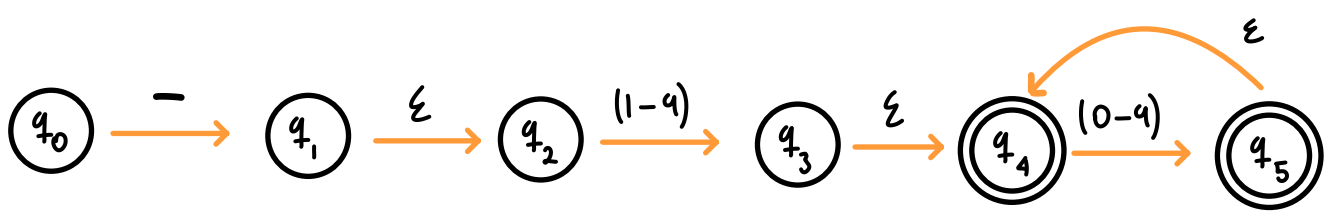
⑤ $(0-9)^*$



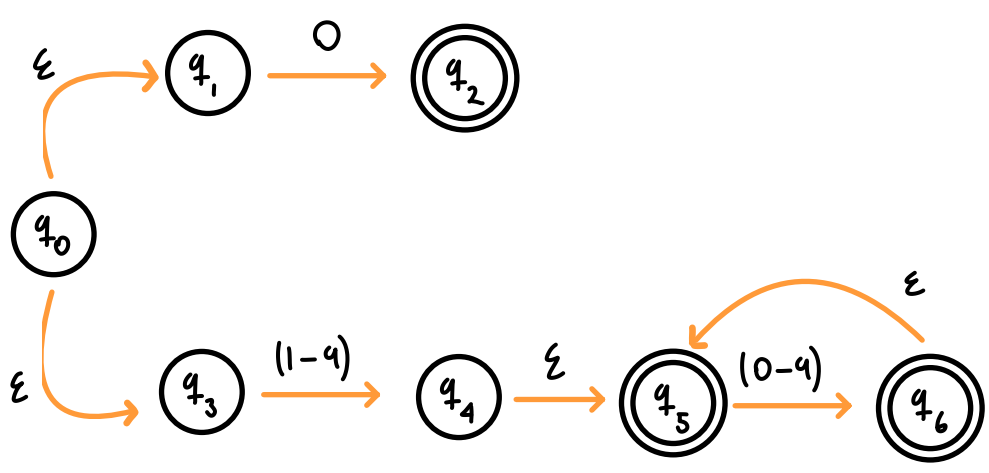
⑥ $(1-9)(0-9)^*$



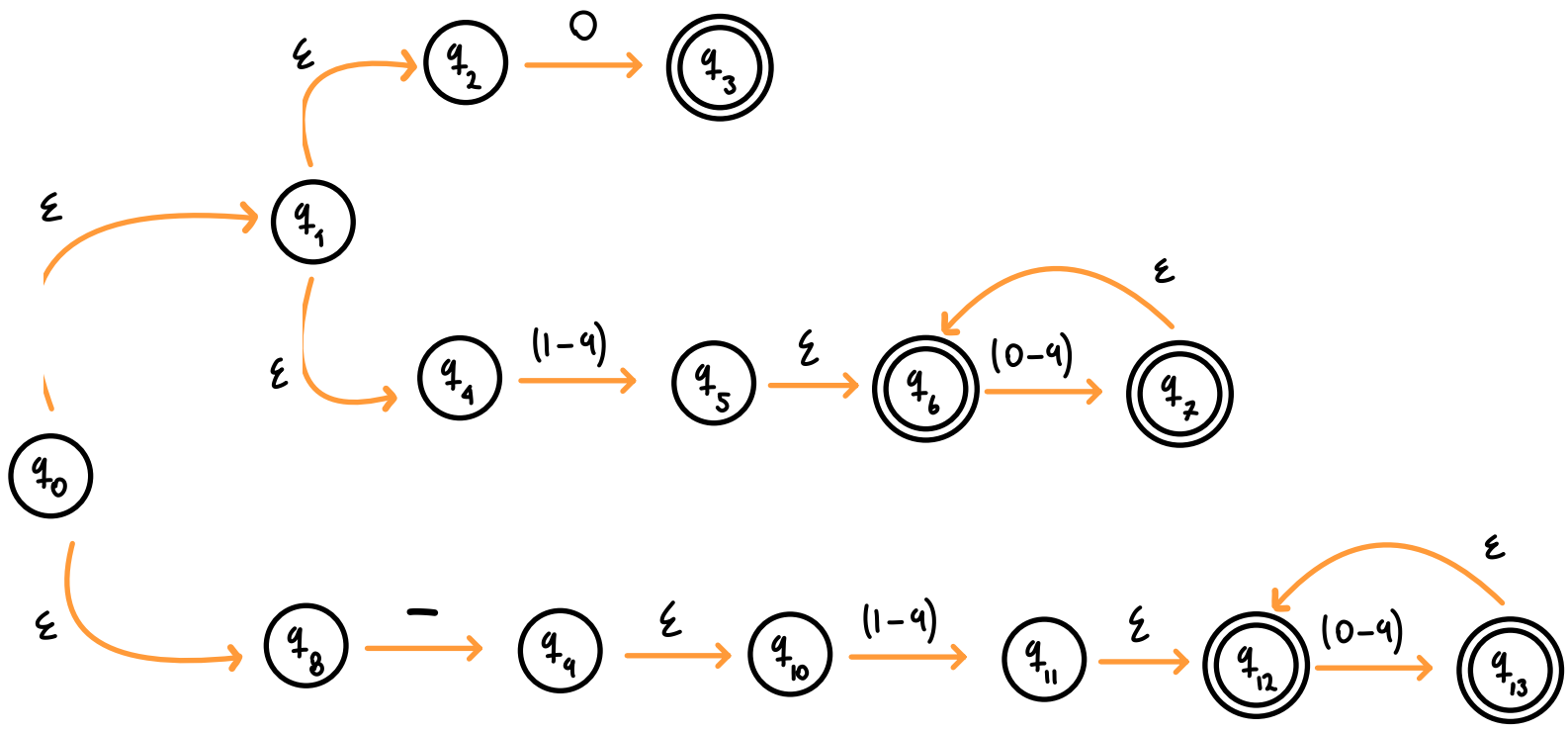
⑦ $-(1-9)(0-9)^*$



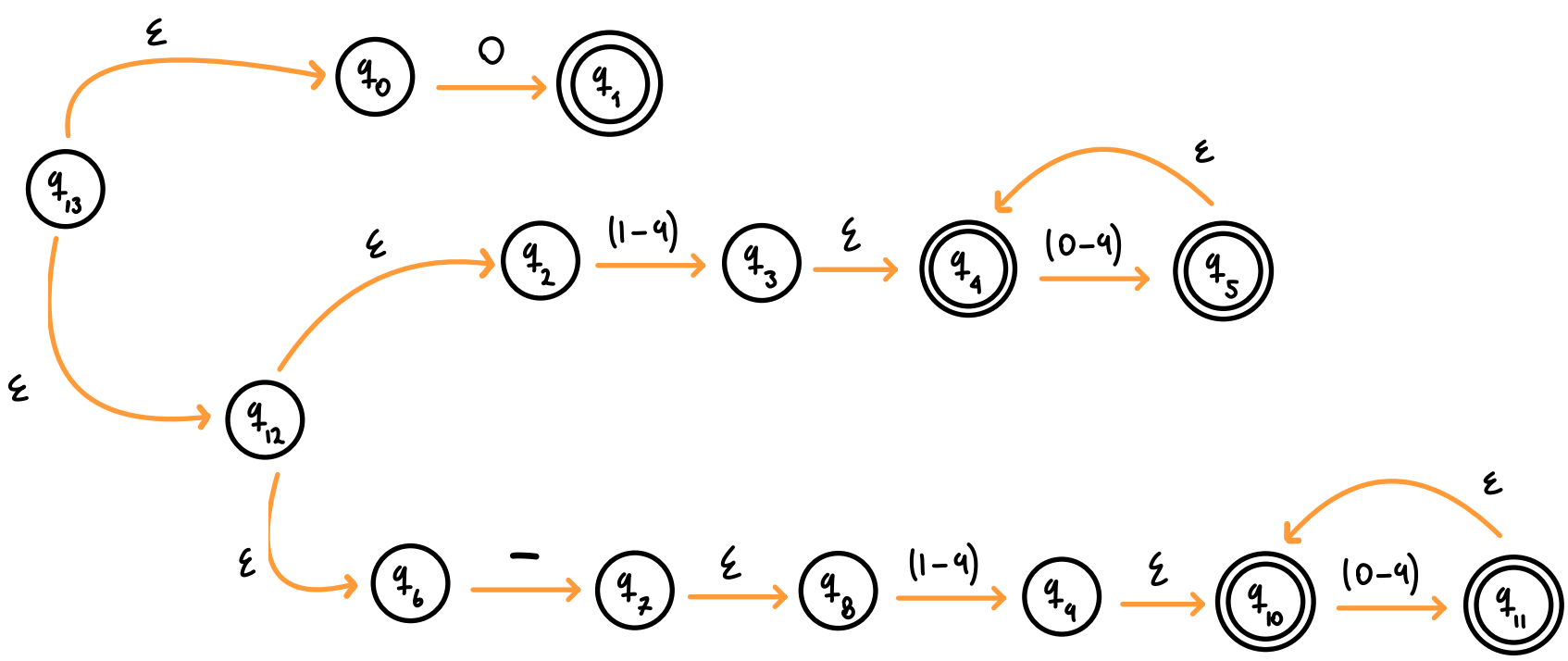
⑧ $0 + (1-9)(0-9)^*$



9 $0 + (1-9)(0-9)^* + -(1-9)(0-9)^*$

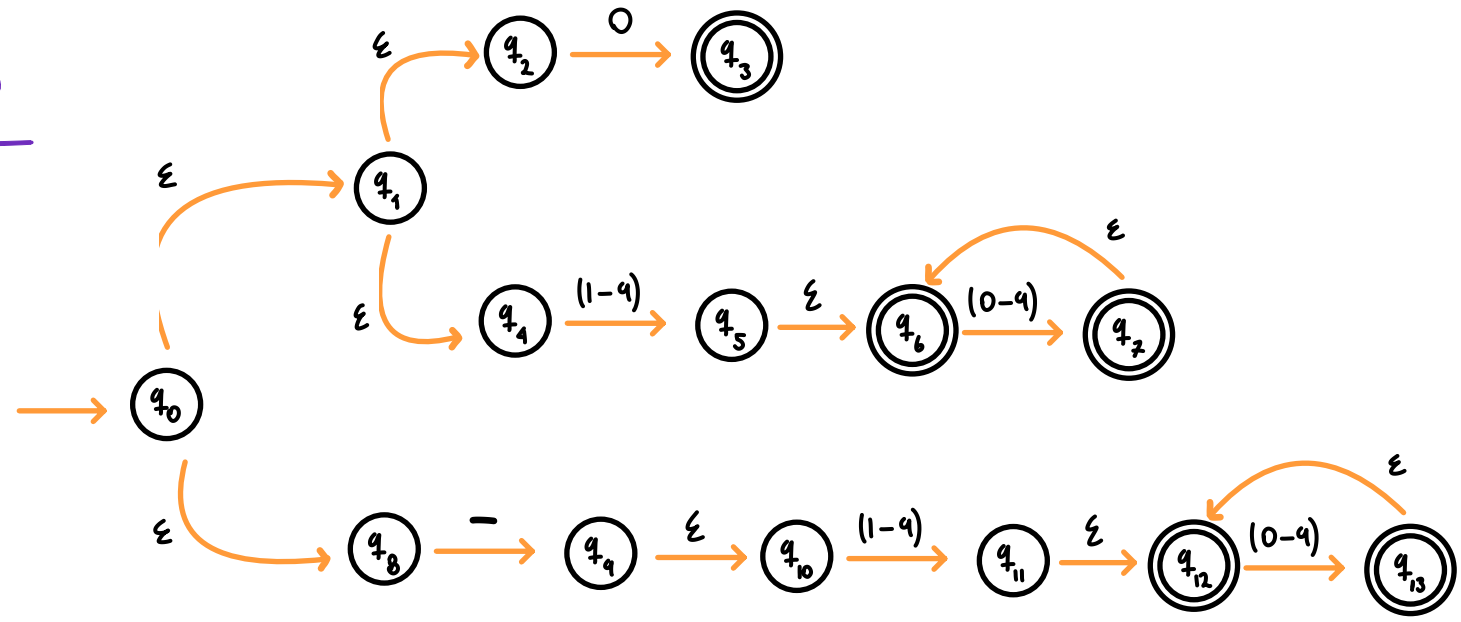


2. AFNε resultante del modulo 'AFNEp.hs'



(2) $AFN_\varepsilon \rightarrow AFN$

1. Proceso a mano



①

- $EC(q_0) = \{q_0, q_1, q_2, q_4, q_8\}$
- $EC(q_1) = \{q_1, q_2, q_4\}$
- $EC(q_2) = \{q_2\}$
- $EC(q_3) = \{q_3\}$
- $EC(q_4) = \{q_4\}$
- $EC(q_5) = \{q_5, q_6\}$
- $EC(q_6) = \{q_6\}$
- $EC(q_7) = \{q_6, q_7\}$
- $EC(q_8) = \{q_8\}$
- $EC(q_9) = \{q_9, q_{10}\}$
- $EC(q_{10}) = \{q_{10}\}$
- $EC(q_{11}) = \{q_{11}, q_{12}\}$
- $EC(q_{12}) = \{q_{12}\}$
- $EC(q_{13}) = \{q_{12}, q_{13}\}$

② $\boxed{q_0}$

- $\delta'(q_0, 0) = EC(\delta(EC(q_0), 0)) = EC(\delta(\{q_0, q_1, q_2, q_4, q_8\}, 0))$
$= EC(q_3) = \{q_3\}$

- $\delta'(q_0, [1-9]) = EC(\delta(EC(q_0), [1-9])) =$
$EC(\delta(\{q_0, q_1, q_2, q_4, q_8\}, [1-9])) = EC(q_5) = \{q_5, q_6\}$

- $\delta'(q_0, [0\text{-}9]) = EC(\delta(EC(q_0), [0\text{-}9])) =$

$EC(\delta(\{q_0, q_1, q_2, q_4, q_8\}, [0\text{-}9])) = EC(\emptyset) = \underline{\underline{\emptyset}}$

- $\delta'(q_0, -) = EC(\delta(EC(q_0), -)) = EC(\delta(\{q_0, q_1, q_2, q_4, q_8\}, -))$

$= EC(q_9) = \underline{\underline{\{q_9, q_{10}\}}}$

$\boxed{q_1}$

- $\delta'(q_1, 0) = EC(\delta(EC(q_1), 0)) =$

$EC(\delta(\{q_1, q_2, q_4\}, 0)) = EC(q_3) = \underline{\underline{\{q_3\}}}$

- $\delta'(q_1, [1\text{-}9]) = EC(\delta(EC(q_1), [1\text{-}9])) =$

$EC(\delta(\{q_1, q_2, q_4\}, [1\text{-}9])) = EC(q_5) = \underline{\underline{\{q_5, q_6\}}}$

- $\delta'(q_1, [0\text{-}9]) = EC(\delta(EC(q_1), [0\text{-}9])) =$

$EC(\delta(\{q_1, q_2, q_4\}, [0\text{-}9])) = EC(\emptyset) = \underline{\underline{\emptyset}}$

- $\delta'(q_1, -) = EC(\delta(EC(q_1), -)) =$

$EC(\delta(\{q_1, q_2, q_4\}, -)) = EC(\emptyset) = \underline{\underline{\emptyset}}$

$\boxed{q_2}$

- $\delta'(q_2, 0) = EC(\delta(EC(q_2), 0)) = EC(\delta(\{q_2\}, 0))$

$= EC(q_3) = \underline{\underline{\{q_3\}}}$

Podemos decir que es trivial que con el resto de los símbolos no llegamos a ningun lado.

$\boxed{q_3}$ Podemos decir que es trivial que con ningún símbolo llegamos a ningun lado.

$\boxed{q_4}$

- $\delta'(q_4, [1\text{-}9]) = EC(\delta(EC(q_4), [1\text{-}9])) =$

$EC(\delta(\{q_4\}, [1\text{-}9])) = EC(q_5) = \{q_5, q_6\}$

Podemos decir que es trivial que con el resto de los símbolos no llegamos a ningun lado.

$\boxed{q_5}$

- $\delta'(q_5, [0\text{-}9]) = EC(\delta(EC(q_5), [0\text{-}9])) =$

$EC(\delta(\{q_5, q_6\}, [0\text{-}9])) = EC(q_7) = \{q_6, q_7\}$

Podemos decir que es trivial que con el resto de los símbolos no llegamos a ningun lado.

$\boxed{q_6}$

- $\delta'(q_6, [0\text{-}9]) = EC(\delta(EC(q_6), [0\text{-}9])) =$

$EC(\delta(\{q_6\}, [0\text{-}9])) = EC(q_7) = \{q_6, q_7\}$

Podemos decir que es trivial que con el resto de los símbolos no llegamos a ningun lado.

$\boxed{q_7}$

- $\delta'(q_7, [0\text{-}9]) = EC(\delta(EC(q_7), [0\text{-}9])) =$

$EC(\delta(\{q_6, q_7\}, [0\text{-}9])) = EC(q_7) = \{q_6, q_7\}$

Podemos decir que es trivial que con el resto de los símbolos no llegamos a ningun lado.

$\boxed{q_8}$ • $\delta'(q_8, -) = EC(\delta(EC(q_8), -)) =$

$EC(\delta(\{q_8\}, -)) = EC(q_9) = \{q_9, q_{10}\}$

Podemos decir que es trivial que con el resto de los símbolos no llegamos a ningun lado.

$\boxed{q_9}$ • $\delta'(q_9, [1-9]) = EC(\delta(EC(q_9), [1-9])) =$

$EC(\delta(\{q_9, q_{10}\}, [1-9])) = EC(q_{11}) = \{q_{11}, q_{12}\}$

Podemos decir que es trivial que con el resto de los símbolos no llegamos a ningun lado.

$\boxed{q_{10}}$ • $\delta'(q_{10}, [1-9]) = EC(\delta(EC(q_{10}), [1-9])) =$

$EC(\delta(\{q_{10}\}, [1-9])) = EC(q_{11}) = \{q_{11}, q_{12}\}$

Podemos decir que es trivial que con el resto de los símbolos no llegamos a ningun lado.

$\boxed{q_{11}}$ • $\delta'(q_{11}, [0-9]) = EC(\delta(EC(q_{11}), [0-9])) =$

$EC(\delta(\{q_{11}, q_{12}\}, [0-9])) = EC(q_{13}) = \{q_{12}, q_{13}\}$

Podemos decir que es trivial que con el resto de los símbolos no llegamos a ningun lado.

$\boxed{q_{12}}$

- $\delta'(q_{12}, [0\text{-}9]) = EC(\delta(EC(q_{12}), [0\text{-}9])) =$

$EC(\delta(\{q_{12}\}, [0\text{-}9])) = EC(q_{13}) = \underline{\underline{\{q_{12}, q_{13}\}}}$

Podemos decir que es trivial que con el resto de los símbolos no llegamos a ningun lado.

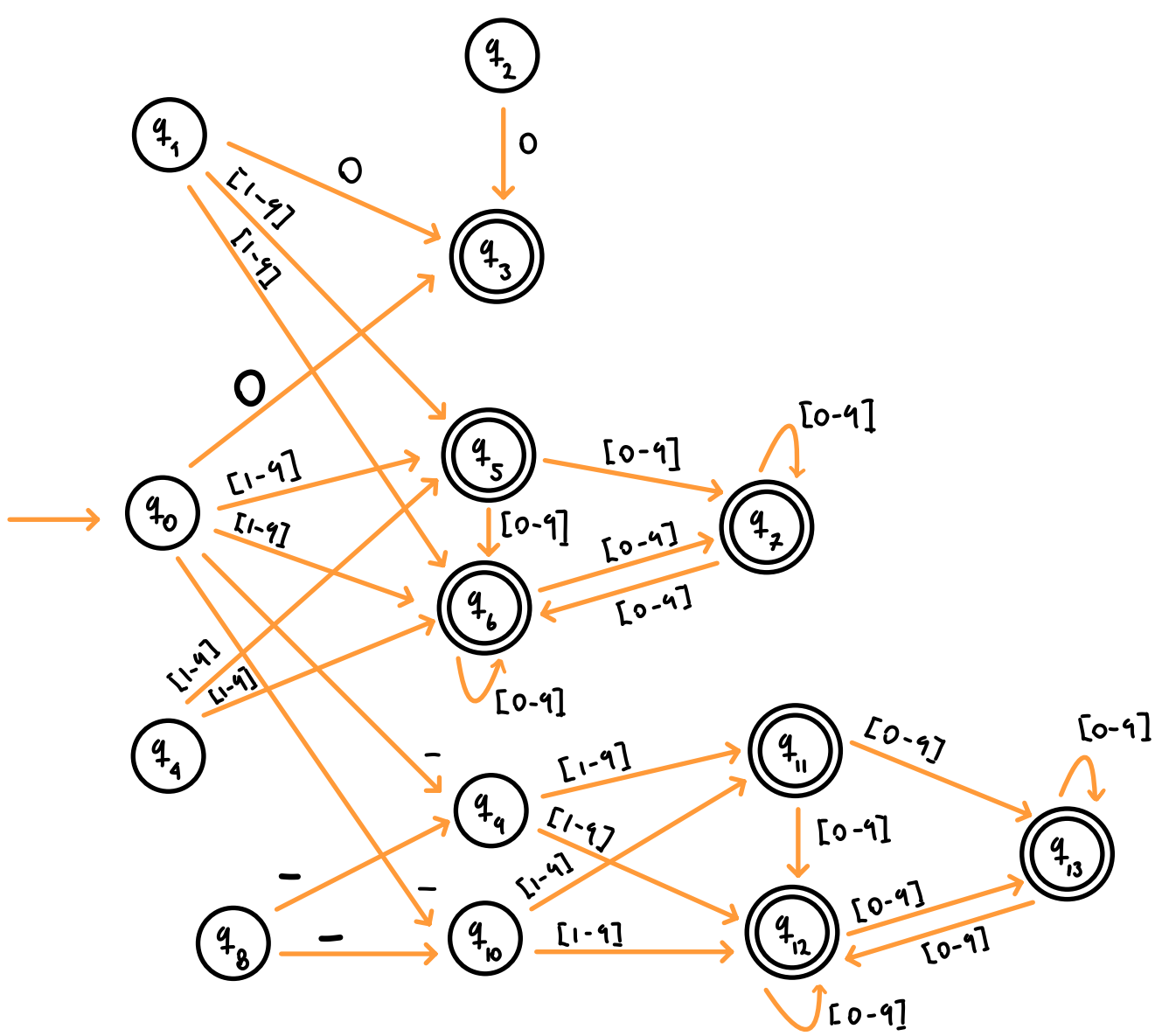
$\boxed{q_{13}}$

- $\delta'(q_{13}, [0\text{-}9]) = EC(\delta(EC(q_{13}), [0\text{-}9])) =$

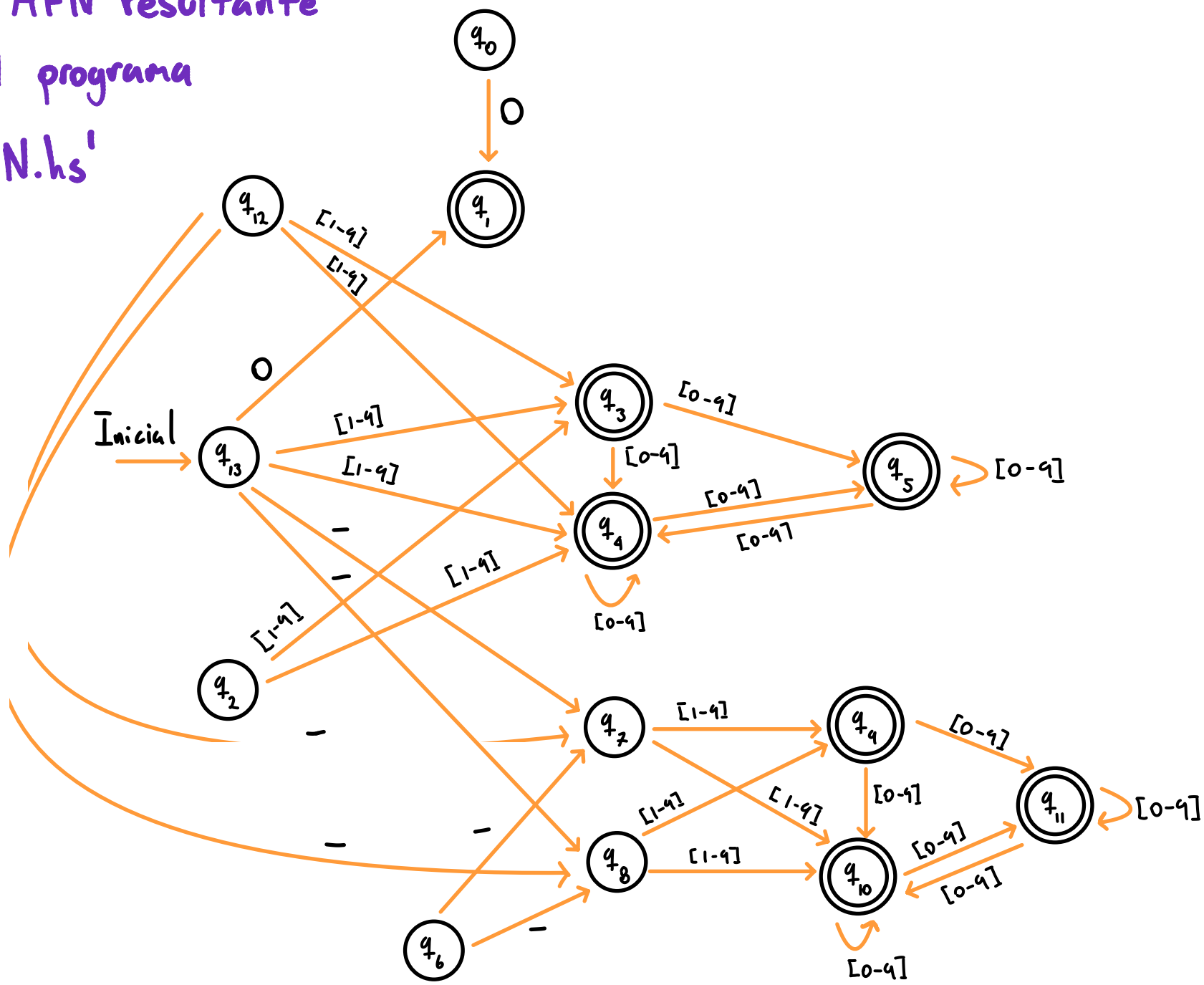
$EC(\delta(\{q_{12}, q_{13}\}, [0\text{-}9])) = EC(q_{13}) = \underline{\underline{\{q_{12}, q_{13}\}}}$

Podemos decir que es trivial que con el resto de los símbolos no llegamos a ningun lado.

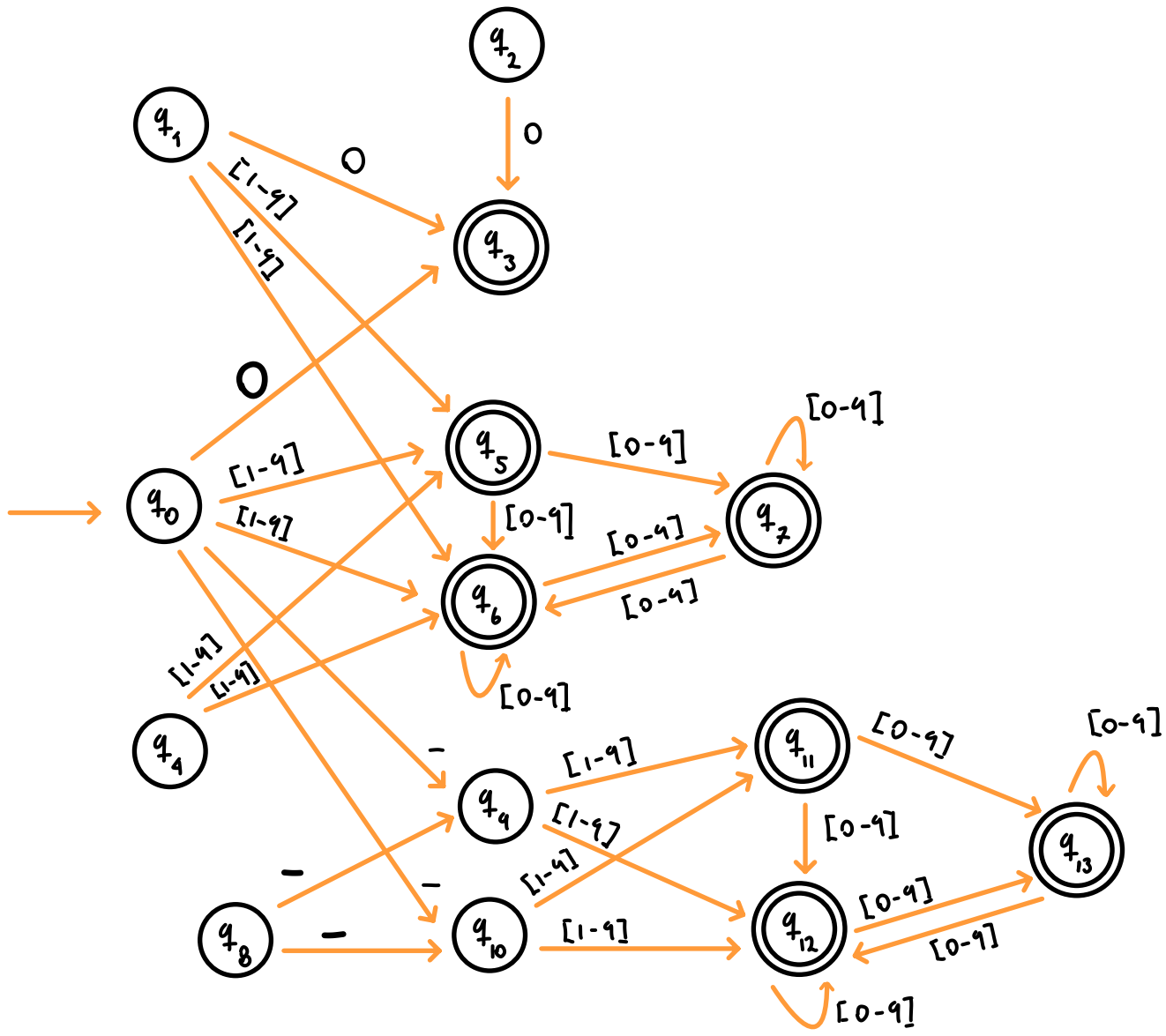
Los nuevos estados finales (dado $F' = \{q \in Q : EC(q) \cap F \neq \emptyset\}$) es $F' = \{q_3, q_5, q_6, q_7, q_{11}, q_{12}, q_{13}\}$



2. AFN resultante del programa 'AFN.hs'



(3) AFN → AFD



1. Proceso a mano

① Construcción por subconjuntos

Iniciamos con $\{q_0\}$

$\{q_0\}$

$\delta(\{q_0\}, 0) = \{q_3\}$

$\delta(\{q_0\}, [1-9]) = \{q_5, q_6\}$

$\delta(\{q_0\}, -) = \{q_9, q_{10}\}$

$\{q_3\} \rightarrow \emptyset$

$\{q_5, q_6\}$

$\delta(\{q_5, q_6\}, [0-9]) = \{q_6, q_7\}$

$\{q_9, q_{10}\}$

$\delta(\{q_9, q_{10}\}, [1-9]) = \{q_{11}, q_{12}\}$

$\{q_6, q_7\}$

$\delta(\{q_6, q_7\}, [0-9]) =$

$\{q_6, q_7\}$

$\{q_{11}, q_{12}\}$

$\delta(\{q_{11}, q_{12}\}, [0-9]) =$

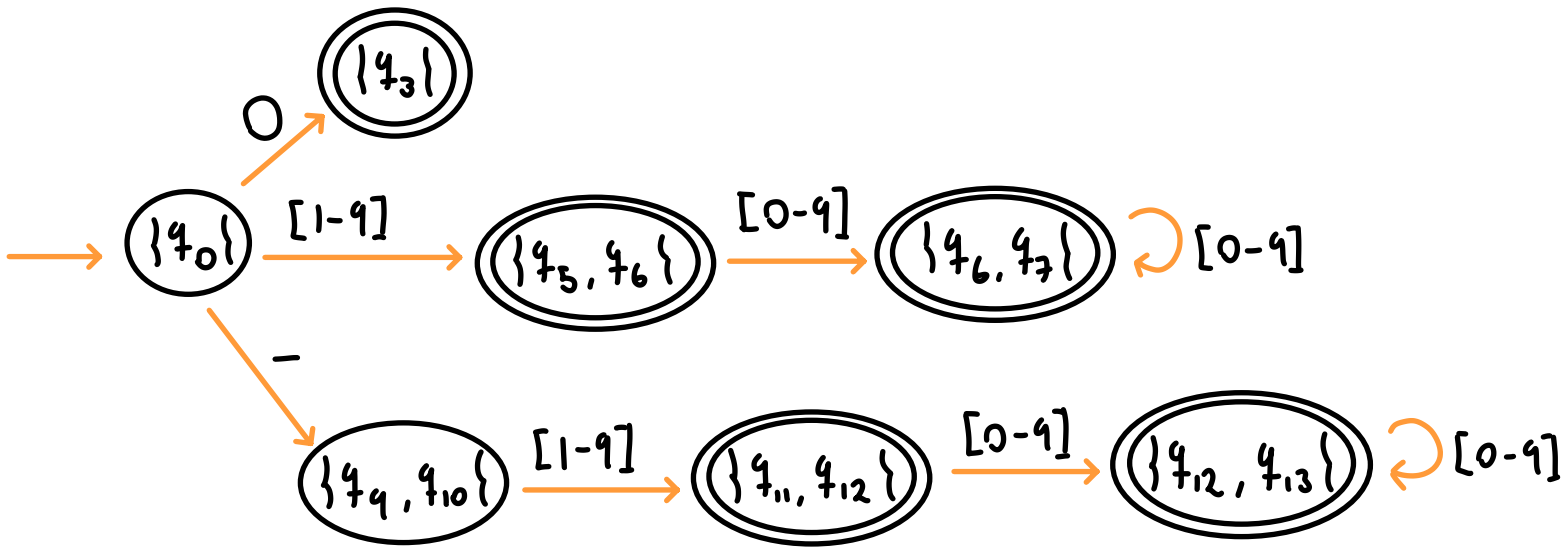
$\{q_{12}, q_{13}\}$

$\{q_{12}, q_{13}\}$ $\delta(\{q_{12}, q_{13}\}, [0-9]) = \{q_{12}, q_{13}\}$

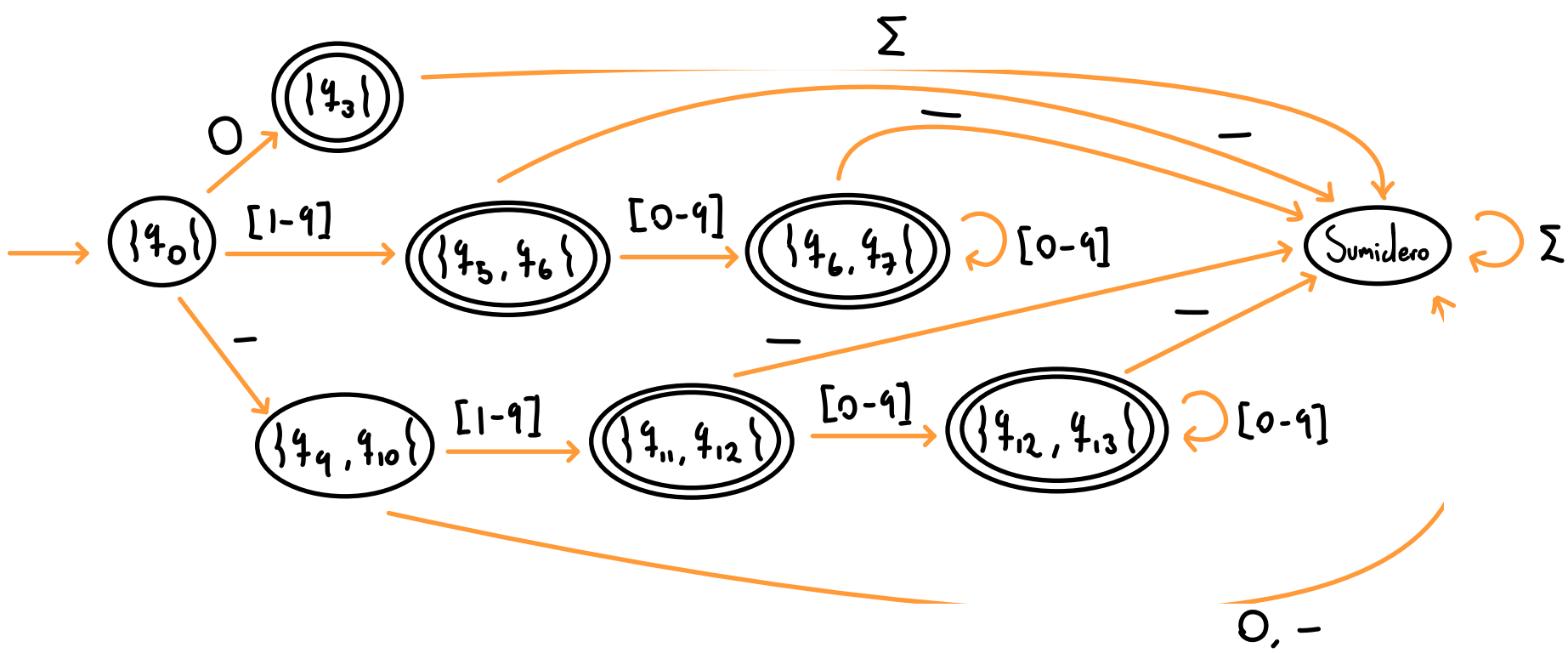
Nuevos estados: $\{q_0\}, \{q_3\}, \{q_5, q_6\}, \{q_9, q_{10}\}, \{q_6, q_7\}, \{q_{11}, q_{12}\}, \{q_{12}, q_{13}\}$

Estados finales: $\{q_3\}, \{q_5, q_6\}, \{q_6, q_7\}, \{q_{11}, q_{12}\}, \{q_{12}, q_{13}\}$

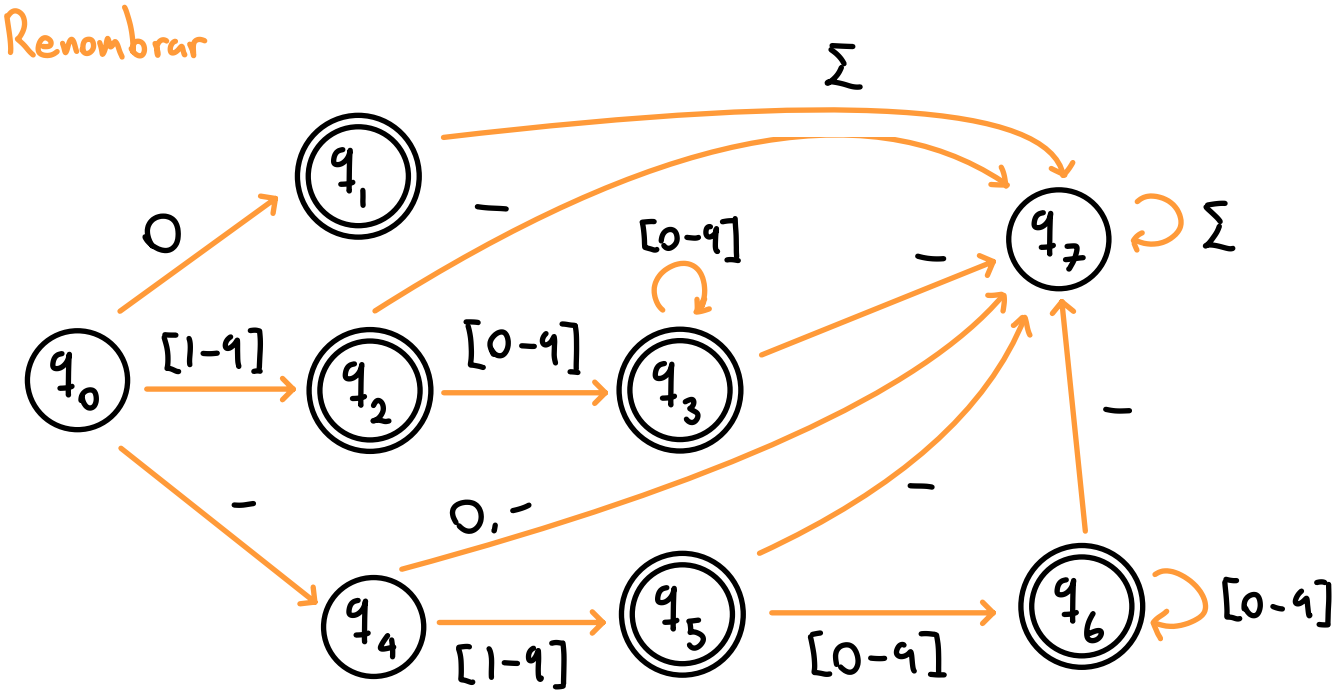
Autómata resultante



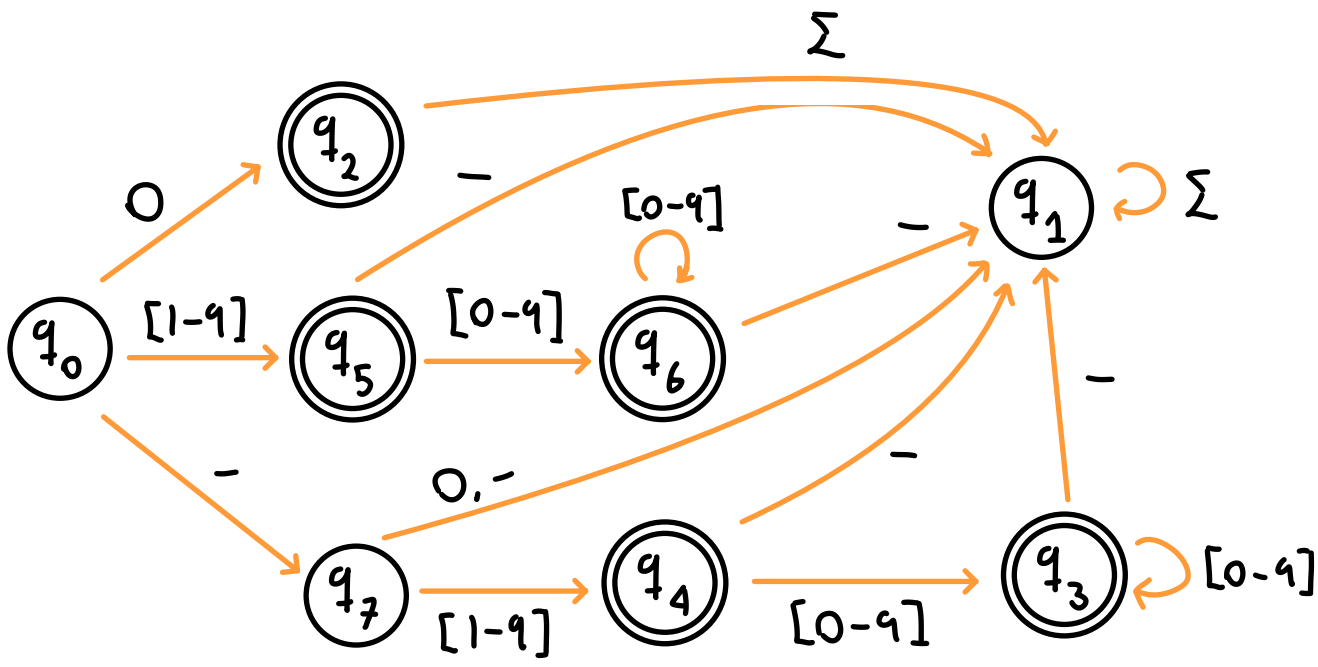
② Completar Autómata



③ Renombrar

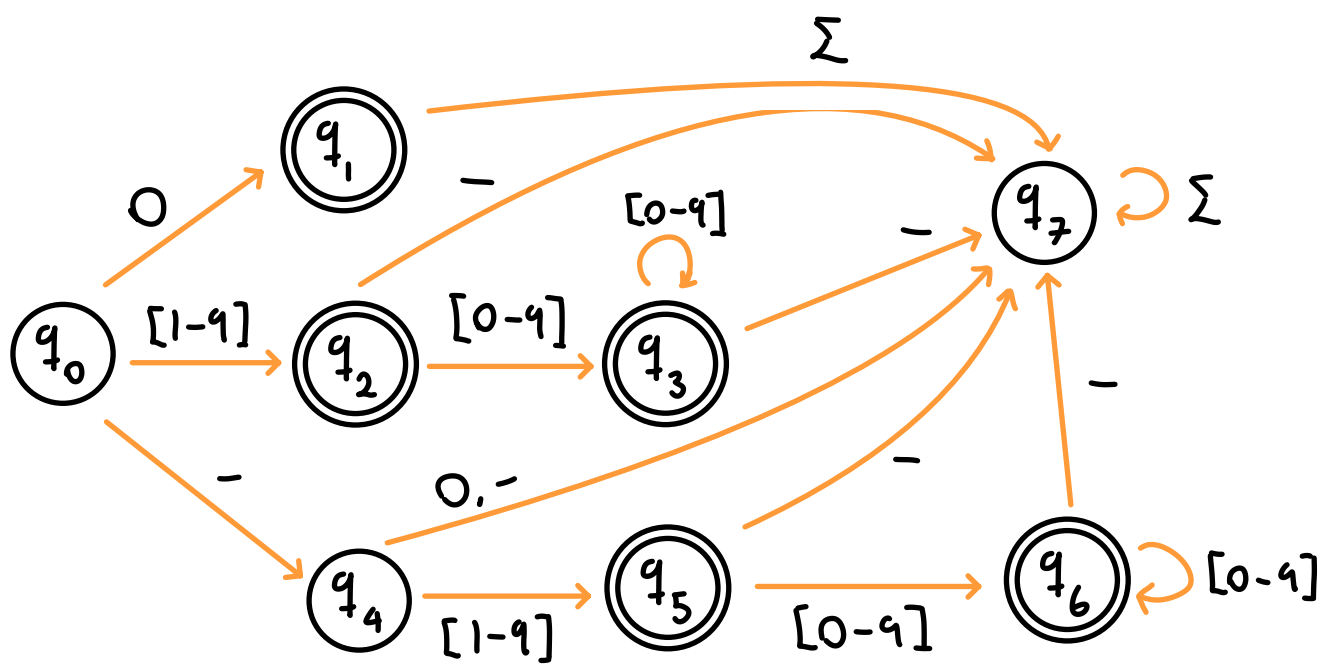


2. AFD resultante del programa 'AFD.hs'



(5) AFD → AFDmin

1. Proceso a mano



① Tabla de pares de estados

	q_0	q_1	q_2	q_3	q_4	q_5	q_6
q_1							
q_2							
q_3							
q_4							
q_5							
q_6							
q_7							

→

	q_0	q_1	q_2	q_3	q_4	q_5	q_6
q_1	X						
q_2	X						
q_3	X						
q_4		X	X	X			
q_5	X				X		
q_6	X				X		
q_7		X	X	X		X	X

② Repetición de paso 2.

$\{q_0, q_4\}$

$\delta(q_0, 0) = q_1$
$\delta(q_4, 0) = q_7$ → $\{q_1, q_7\}$

Si esta marcado

$\delta(q_0, [1-9]) = q_2$
$\delta(q_4, [1-9]) = q_5$ → $\{q_2, q_5\}$

$\delta(q_0, -) = q_4$
$\delta(q_4, -) = q_7$ → $\{q_4, q_7\}$

∴ Marcamos $\{q_0, q_4\}$

$\{q_0, q_7\}$

$\delta(q_0, 0) = q_1 \searrow$

$\delta(q_7, 0) = q_7 \nearrow \{q_1, q_7\}$

Si esta marcado

$\therefore$ Marcamos $\{q_0, q_7\}$

$\{q_1, q_2\}$

$\delta(q_1, 0) = q_7 \searrow$

$\delta(q_2, 0) = q_3 \nearrow \{q_3, q_7\}$

Si esta marcado

$\therefore$ Marcamos $\{q_1, q_2\}$

$\{q_1, q_3\}$

$\delta(q_1, 0) = q_7 \searrow$

$\delta(q_3, 0) = q_3 \nearrow \{q_3, q_7\}$

Si esta marcado

$\therefore$ Marcamos $\{q_1, q_3\}$

$\{q_1, q_5\}$

$\delta(q_1, 0) = q_7 \searrow$

$\delta(q_5, 0) = q_6 \nearrow \{q_6, q_7\}$

Si esta marcado

$\therefore$ Marcamos $\{q_1, q_5\}$

$\{q_1, q_6\}$

$\delta(q_1, 0) = q_7 \searrow$

$\delta(q_6, 0) = q_6 \nearrow \{q_6, q_7\}$

Si esta marcado

$\therefore$ Marcamos $\{q_1, q_6\}$

$\{q_2, q_3\}$

$\delta(q_2, [0\text{-}9]) = q_3 \searrow$

$\delta(q_3, [0\text{-}9]) = q_3 \nearrow \{q_3, q_3\}$

$\delta(q_2, -) = q_7 \searrow$

$\delta(q_3, -) = q_7 \nearrow \{q_7, q_7\}$

$\therefore$ Sin marcar

$\{q_2, q_5\}$

$\delta(q_2, [0\text{-}9]) = q_3 \searrow$

$\delta(q_5, [0\text{-}9]) = q_6 \nearrow \{q_3, q_6\}$

$\delta(q_2, -) = q_7 \searrow$

$\delta(q_5, -) = q_7 \nearrow \{q_7, q_7\}$

$\therefore$ Sin marcar

$\{q_2, q_6\}$

$\delta(q_2, [0\text{-}9]) = q_3 \searrow$

$\delta(q_6, [0\text{-}9]) = q_6 \nearrow \{q_3, q_6\}$

$\delta(q_2, -) = q_7 \searrow$

$\delta(q_6, -) = q_7 \nearrow \{q_7, q_7\}$

$\therefore$ Sin marcar

$\{q_3, q_5\}$

$\delta(q_3, [0\text{-}9]) = q_3$
$\delta(q_5, [0\text{-}9]) = q_6$ $\rightarrow \{q_3, q_6\}$

$\delta(q_3, -) = q_7$
$\delta(q_5, -) = q_7$ $\rightarrow \{q_7, q_7\}$

$\therefore$ Sin marcar

$\{q_3, q_6\}$

$\delta(q_3, [0\text{-}9]) = q_3$
$\delta(q_6, [0\text{-}9]) = q_6$ $\rightarrow \{q_3, q_6\}$

$\delta(q_3, -) = q_7$
$\delta(q_6, -) = q_7$ $\rightarrow \{q_7, q_7\}$

$\therefore$ Sin marcar

$\{q_4, q_7\}$

$\delta(q_4, [1\text{-}9]) = q_5$
$\delta(q_7, [1\text{-}9]) = q_7$ $\rightarrow \{q_5, q_7\}$

Si esta marcado

$\therefore$ Marcamos $\{q_4, q_7\}$

$\{q_5, q_6\}$

$\delta(q_5, [0\text{-}9]) = q_6$
$\delta(q_6, [0\text{-}9]) = q_6$ $\rightarrow \{q_6, q_6\}$

$\delta(q_5, -) = q_7$
$\delta(q_6, -) = q_7$ $\rightarrow \{q_7, q_7\}$

$\therefore$ Sin marcar

La tabla final:

	q_0	q_1	q_2	q_3	q_4	q_5	q_6
q_1	X						
q_2	X	X					
q_3	X	X					
q_4	X	X	X	X			
q_5	X	X			X		
q_6	X	X			X		
q_7	X	X	X	X	X	X	X

3 Fusionar estados equivalentes

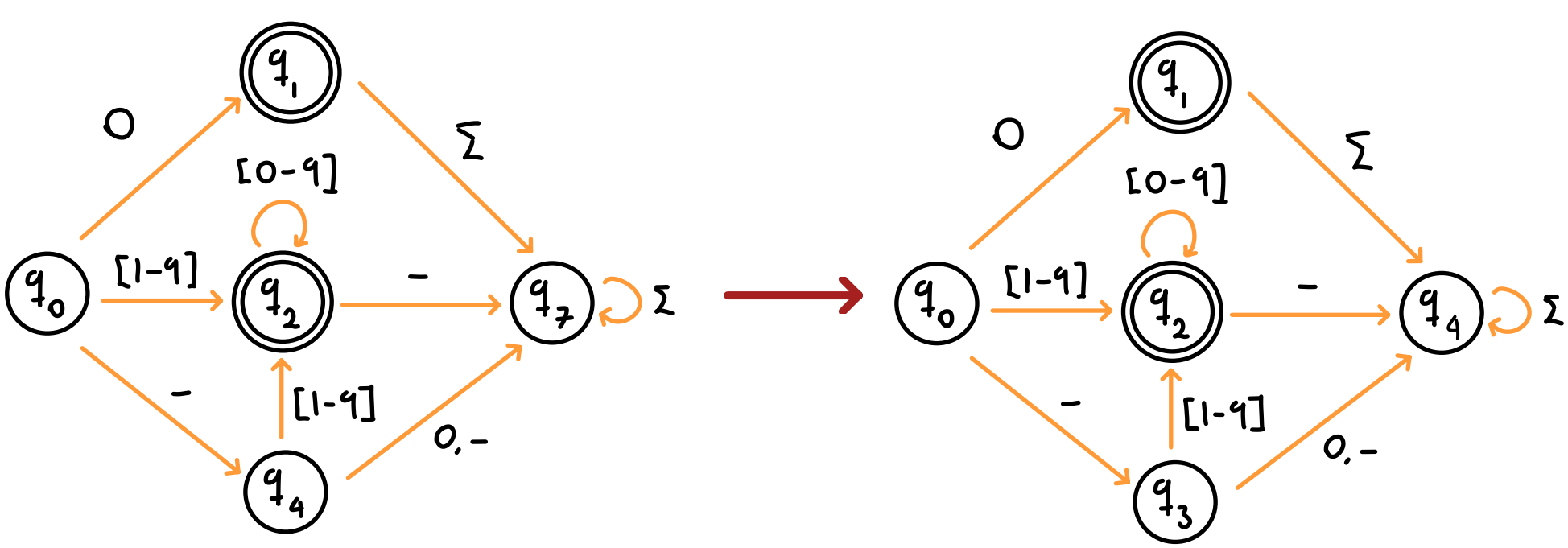
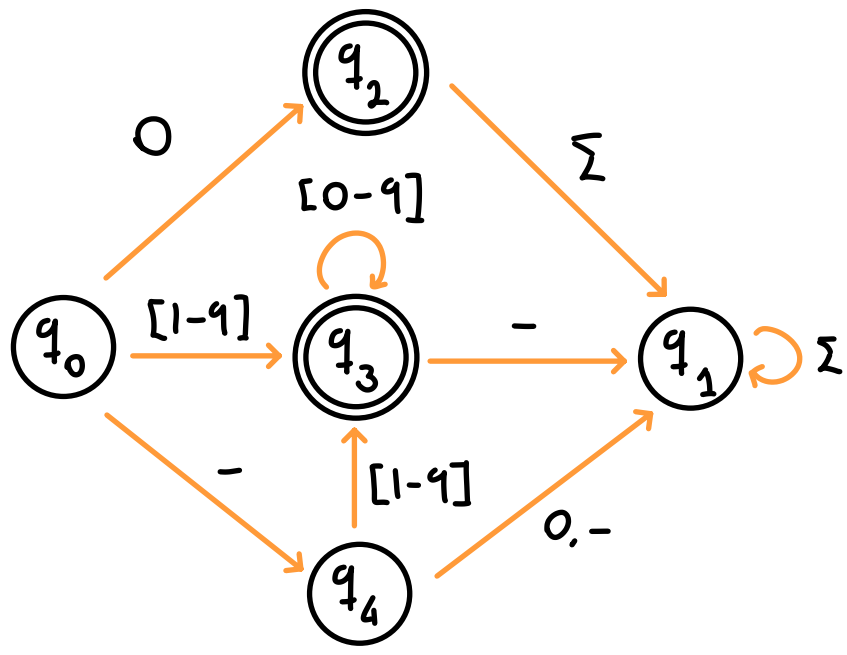
Tenemos lo siguiente

$q_2 \approx q_3$, $q_2 \approx q_5$, $q_2 \approx q_6$, $q_3 \approx q_5$, $q_3 \approx q_6$

y $q_5 \approx q_6$

$\Longrightarrow q_2 \approx q_3 \approx q_5 \approx q_6$

Colapsamos estos estados y sus transiciones:



2. AFD_{min} resultante del programa 'AFDmin.hs'