DEPARTMENT OF
NETWORKED SYSTEMS
AND SERVICES

COMPUTER ARCHITECTURES

Practical Tasks in:

Branch Prediction

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TASK 1 – SIMPLE FSM-BASED

- During the execution of a program, the processor evaluates conditional branch instructions located at the following addresses (T: jump is taken, N: jump is not taken):
- 464 (T), 543 (N), 777 (N), 543 (N), 777 (N), 464 (T), 777 (N), 464 (T), 543 (T)
- The processor uses a simple, 2-bit Finite State Machine based dynamic branch prediction, and it is able to follow 4 conditional jump instructions.
  a) How many bits are needed to store the Pattern History Table?
  b) Give the content of the PHT after the execution of every single instruction. Signal, if the prediction of the outcome was successful (S), or failed (F). The initial value of each state machine is 1.

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TASK 1 – SOLUTION

a) How many bits are needed to store the Pattern History Table?

- As the processor is able to follow 4 conditional jump instructions, its PHT has 4 entries.
- Each entry needs 2 bits.
- 4x2=**8** bits are needed to store the PHT.

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TASK 1 – SOLUTION

b) Give the content of the PHT after the execution of every single instruction. Signal, if the prediction of the outcome was successful (S), or failed (F). The initial value of each state machine is 1.

- First, we determine, which conditional jump instruction is mapped to which state machine.
- The hash function takes the last two bits, or with other words, we need to consider the **modulo 4** values of the addresses
- 464 (T), 543 (N), 777 (N), 543 (N), 777 (N), 464 (T), 777 (N), 464 (T), 543 (T) →
- **0 (T), 3 (N), 1 (N), 3 (N), 1 (N), 0 (T), 1 (N), 0 (T), 3 (T)**

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TASK 1 – SOLUTION

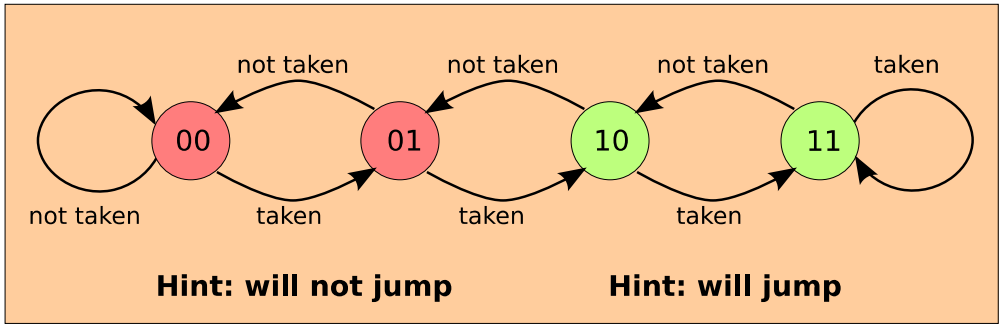
0 (T), 3 (N), 1 (N), 3 (N), 1 (N), 0 (T), 1 (N), 0 (T), 3 (T)

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1									
1	1									
2	1									
3	1									

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TASK 1 – SOLUTION

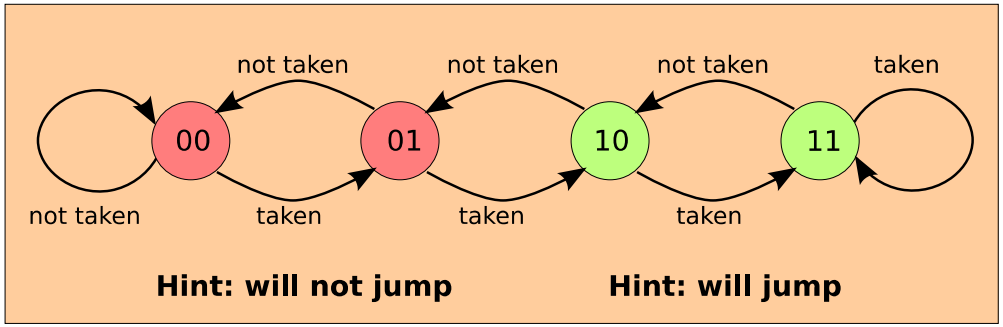
0 (T), 3 (N), 1 (N), 3 (N), 1 (N), 0 (T), 1 (N), 0 (T), 3 (T)

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1									
1	1									
2	1									
3	1									

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TASK 1 – SOLUTION

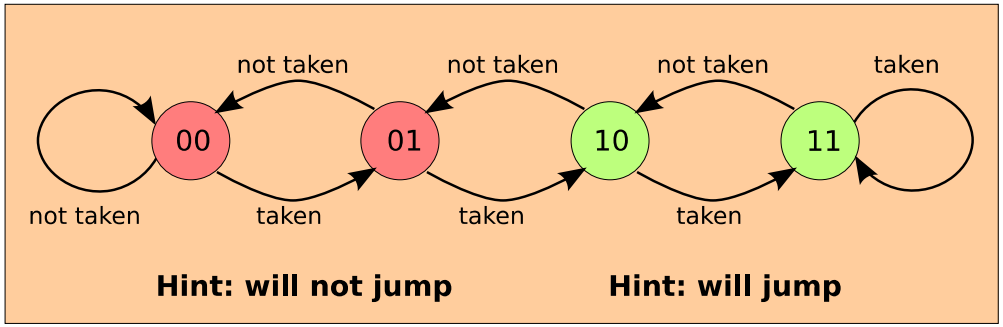
0 (T), 3 (N), 1 (N), 3 (N), 1 (N), 0 (T), 1 (N), 0 (T), 3 (T)

Prediction: will not jump

Actual behavior: T

Prediction: Failed

FSM: 1 → 2



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1									
1	1									
2	1									
3	1									

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TASK 1 – SOLUTION

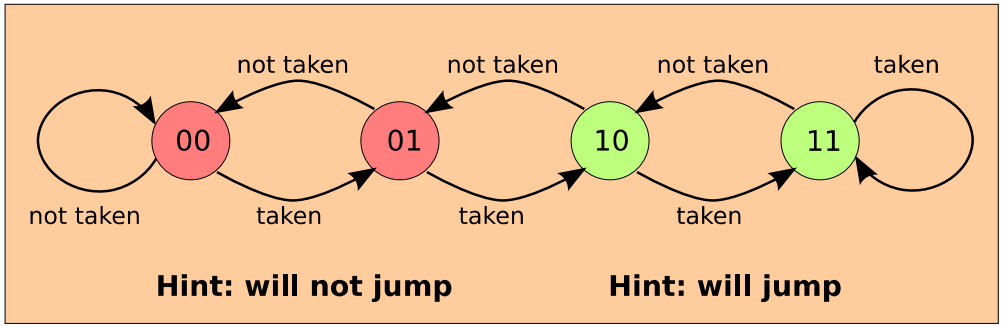
0 (T), 3 (N), 1 (N), 3 (N), 1 (N), 0 (T), 1 (N), 0 (T), 3 (T)

Prediction: will not jump

Actual behavior: T

Prediction: Failed

FSM: 1 → 2



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**								
1	1	1								
2	1	1								
3	1	1								

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TASK 1 – SOLUTION

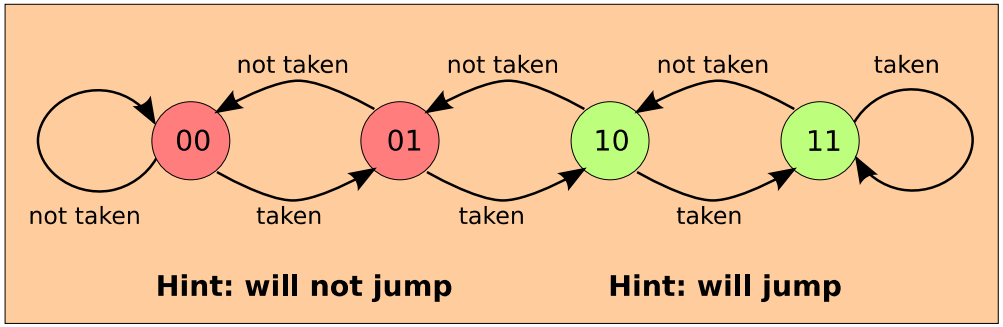
0 (T), **3** (N), 1 (N), 3 (N), 1 (N), 0 (T), 1 (N), 0 (T), 3 (T)

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**								
1	1	1								
2	1	1								
3	1	1								

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TASK 1 – SOLUTION

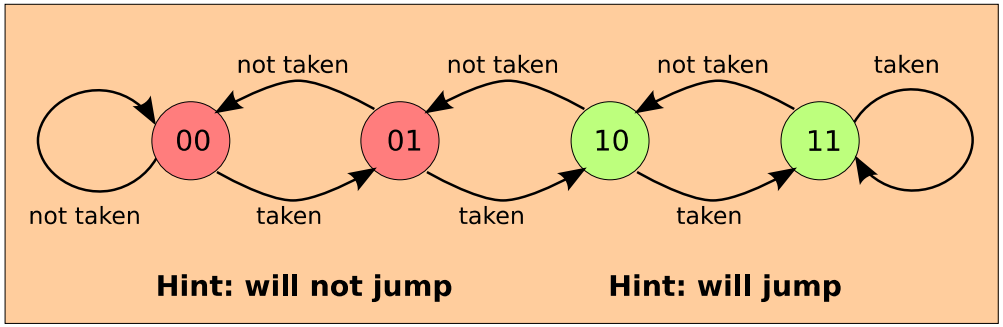
0 (T), **3** (N), 1 (N), 3 (N), 1 (N), 0 (T), 1 (N), 0 (T), 3 (T)

Prediction: will not jump

Actual behavior: N

Prediction: Successful

FSM: 1 → 0



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**								
1	1	1								
2	1	1								
3	1	1								

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TASK 1 – SOLUTION

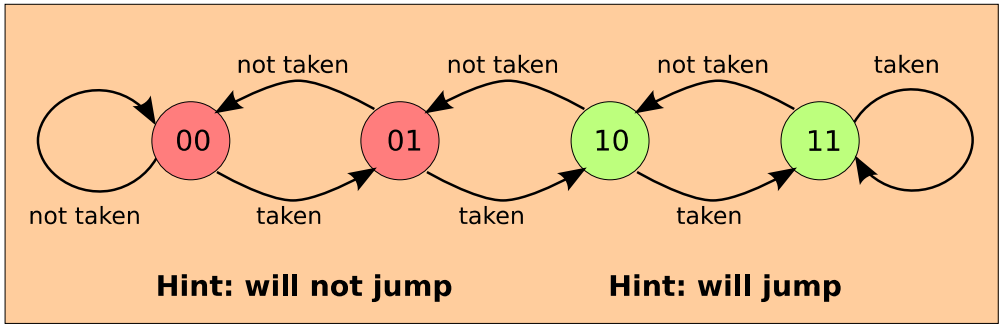
0 (T), **3** (N), 1 (N), 3 (N), 1 (N), 0 (T), 1 (N), 0 (T), 3 (T)

Prediction: will not jump

Actual behavior: N

Prediction: Successful

FSM: 1 → 0



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2							
1	1	1	1							
2	1	1	1							
3	1	1	**0 S**							

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TASK 1 – SOLUTION

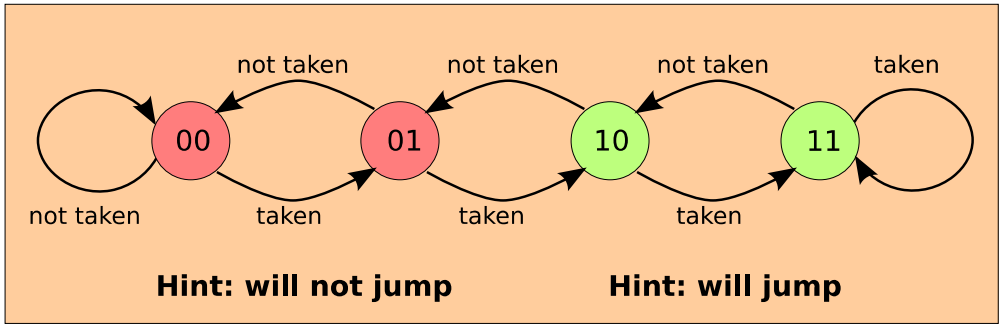
0 (T), 3 (N), **1** (N), 3 (N), 1 (N), 0 (T), 1 (N), 0 (T), 3 (T)

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2							
1	1	1	1							
2	1	1	1							
3	1	1	**0 S**							

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TASK 1 – SOLUTION

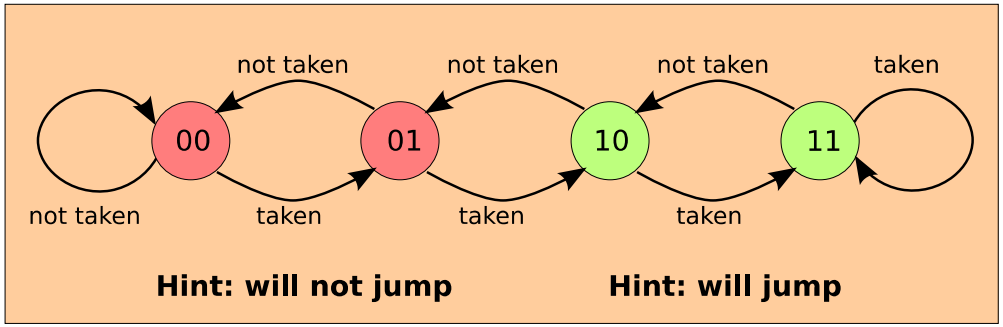
0 (T), 3 (N), **1** (N), 3 (N), 1 (N), 0 (T), 1 (N), 0 (T), 3 (T)

Prediction: will not jump

Actual behavior: N

Prediction: Successful

FSM: 1 → 0



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2							
1	1	1	1							
2	1	1	1							
3	1	1	**0 S**							

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TASK 1 – SOLUTION

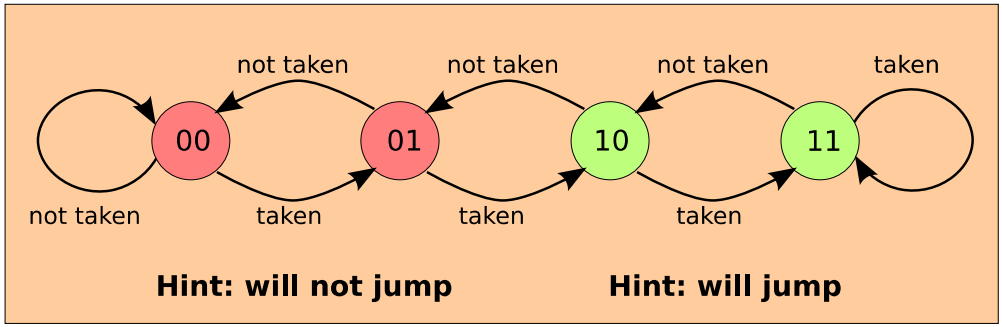
0 (T), 3 (N), **1** (N), 3 (N), 1 (N), 0 (T), 1 (N), 0 (T), 3 (T)

Prediction: will not jump

Actual behavior: N

Prediction: Successful

FSM: 1 → 0



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2						
1	1	1	1	**0 S**						
2	1	1	1	1						
3	1	1	**0 S**	0						

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TASK 1 – SOLUTION

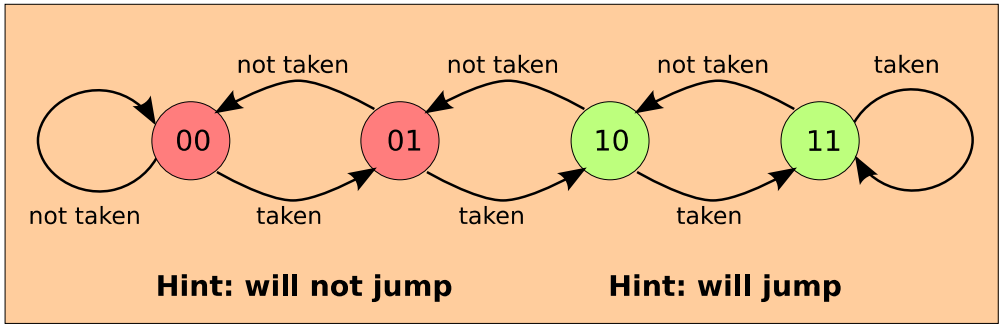
0 (T), 3 (N), 1 (N), **3** (N), 1 (N), 0 (T), 1 (N), 0 (T), 3 (T)

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2						
1	1	1	1	**0 S**						
2	1	1	1	1						
3	1	1	**0 S**	0						

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TASK 1 – SOLUTION

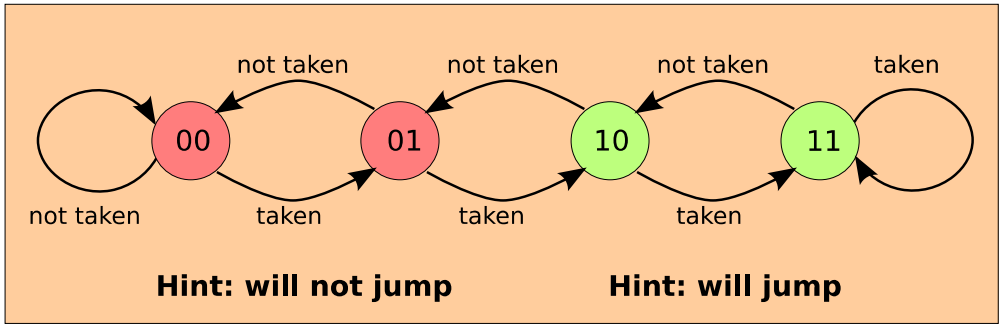
0 (T), 3 (N), 1 (N), **3** (N), 1 (N), 0 (T), 1 (N), 0 (T), 3 (T)

Prediction: will not jump

Actual behavior: N

Prediction: Successful

FSM: 0 → 0 (saturated)



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2						
1	1	1	1	**0 S**						
2	1	1	1	1						
3	1	1	**0 S**	0						

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TASK 1 – SOLUTION

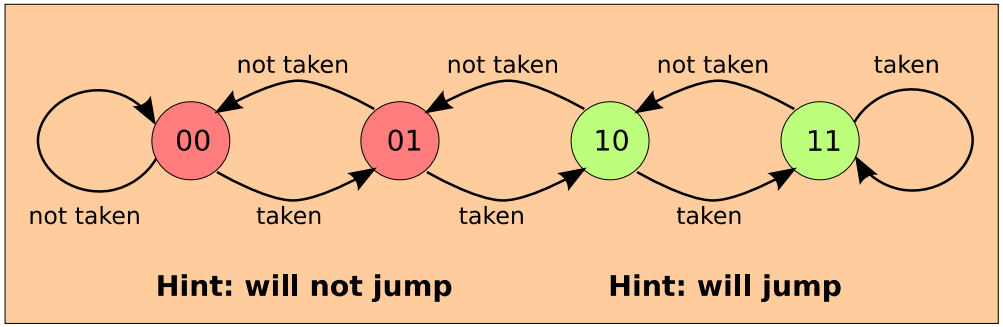
0 (T), 3 (N), 1 (N), **3** (N), 1 (N), 0 (T), 1 (N), 0 (T), 3 (T)

Prediction: will not jump

Actual behavior: N

Prediction: Successful

FSM: 0 → 0 (saturated)



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2	2					
1	1	1	1	**0 S**	0					
2	1	1	1	1	1					
3	1	1	**0 S**	0	**0 S**					

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TASK 1 – SOLUTION

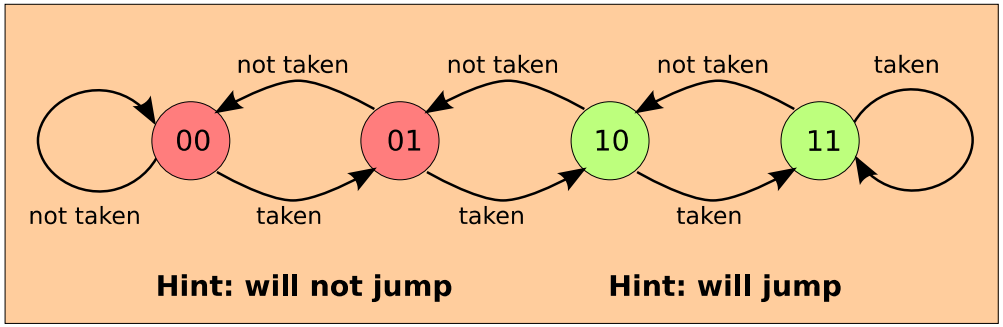
0 (T), 3 (N), 1 (N), 3 (N), **1** (N), 0 (T), 1 (N), 0 (T), 3 (T)

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2	2					
1	1	1	1	**0 S**	0					
2	1	1	1	1	1					
3	1	1	**0 S**	0	**0 S**					

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TASK 1 – SOLUTION

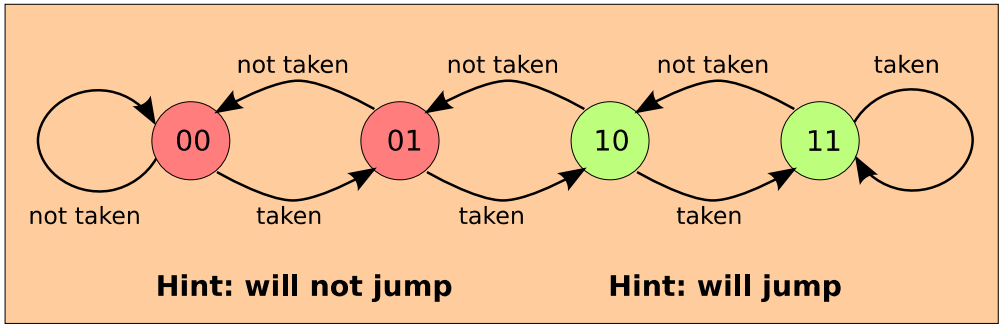
0 (T), 3 (N), 1 (N), 3 (N), **1** (N), 0 (T), 1 (N), 0 (T), 3 (T)

Prediction: will not jump

Actual behavior: N

Prediction: Successful

FSM: 0 → 0 (saturated)



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2	2					
1	1	1	1	**0 S**	0					
2	1	1	1	1	1					
3	1	1	**0 S**	0	**0 S**					

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TASK 1 – SOLUTION

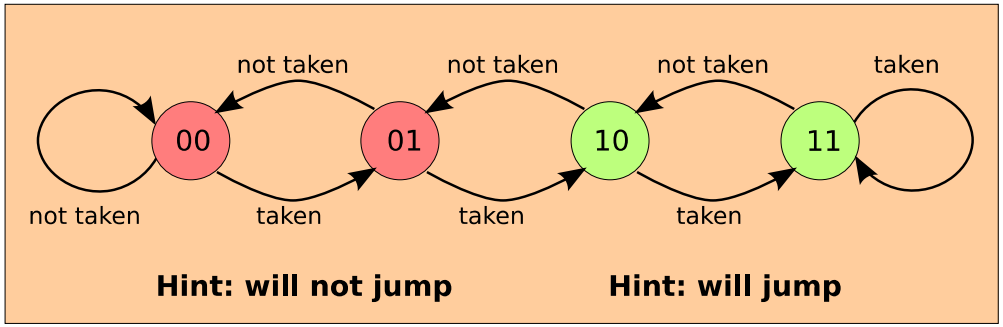
0 (T), 3 (N), 1 (N), 3 (N), **1** (N), 0 (T), 1 (N), 0 (T), 3 (T)

Prediction: will not jump

Actual behavior: N

Prediction: Successful

FSM: 0 → 0 (saturated)



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2	2	2				
1	1	1	1	**0 S**	0	**0 S**				
2	1	1	1	1	1	1				
3	1	1	**0 S**	0	**0 S**	0				

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TASK 1 – SOLUTION

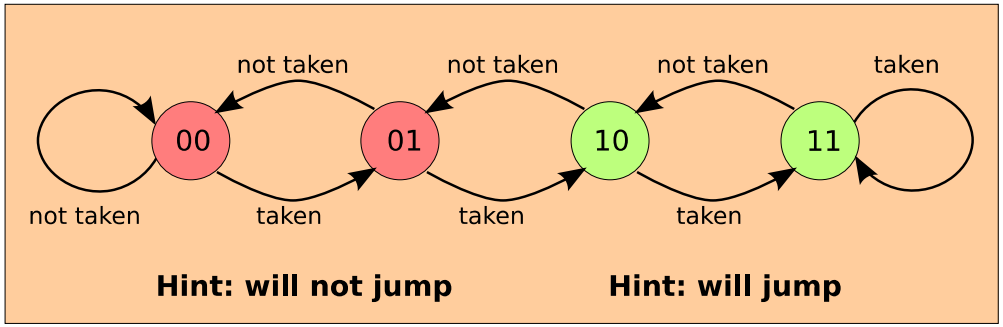
0 (T), 3 (N), 1 (N), 3 (N), 1 (N), **0** (T), 1 (N), 0 (T), 3 (T)

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2	2	2				
1	1	1	1	**0 S**	0	**0 S**				
2	1	1	1	1	1	1				
3	1	1	**0 S**	0	**0 S**	0				

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TASK 1 – SOLUTION

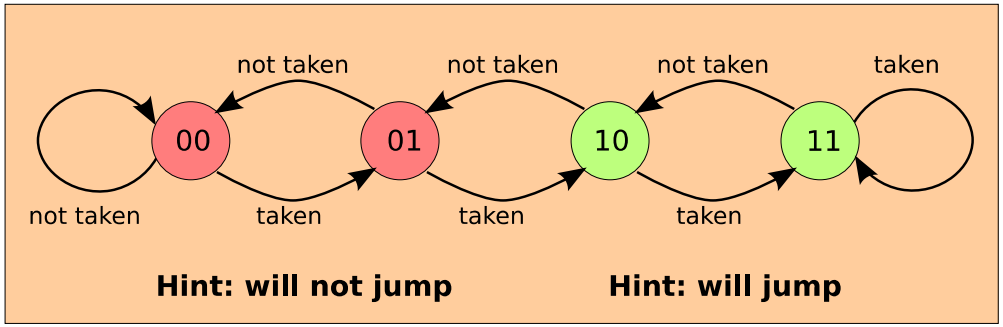
0 (T), 3 (N), 1 (N), 3 (N), 1 (N), **0** (T), 1 (N), 0 (T), 3 (T)

Prediction: will jump

Actual behavior: T

Prediction: Successful

FSM: 2 → 3



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2	2	2				
1	1	1	1	**0 S**	0	**0 S**				
2	1	1	1	1	1	1				
3	1	1	**0 S**	0	**0 S**	0				

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TASK 1 – SOLUTION

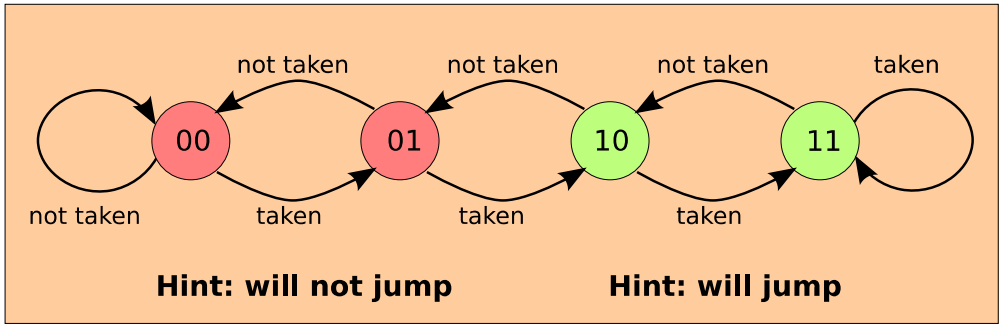
0 (T), 3 (N), 1 (N), 3 (N), 1 (N), **0** (T), 1 (N), 0 (T), 3 (T)

Prediction: will jump

Actual behavior: T

Prediction: Successful

FSM: 2 → 3



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2	2	2	**3 S**			
1	1	1	1	**0 S**	0	**0 S**	0			
2	1	1	1	1	1	1	1			
3	1	1	**0 S**	0	**0 S**	0	0			

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TASK 1 – SOLUTION

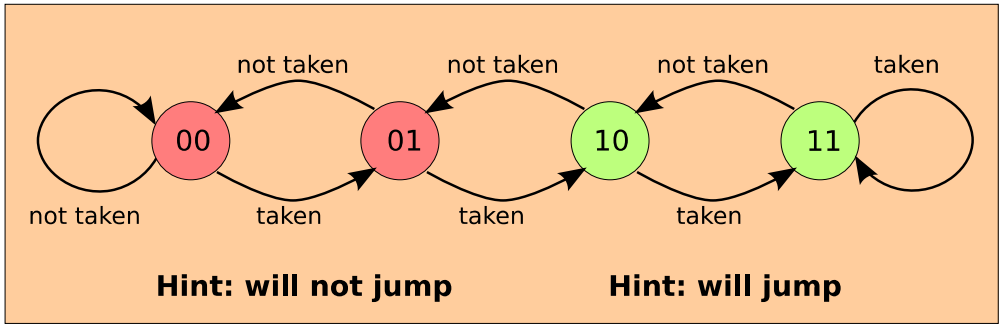
0 (T), 3 (N), 1 (N), 3 (N), 1 (N), 0 (T), **1** (N), 0 (T), 3 (T)

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2	2	2	**3 S**			
1	1	1	1	**0 S**	0	**0 S**	0			
2	1	1	1	1	1	1	1			
3	1	1	**0 S**	0	**0 S**	0	0			

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TASK 1 – SOLUTION

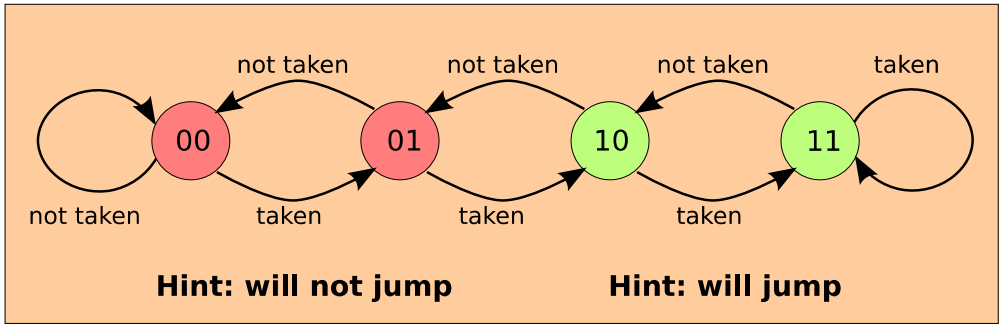
0 (T), 3 (N), 1 (N), 3 (N), 1 (N), 0 (T), **1** (N), 0 (T), 3 (T)

Prediction: will not jump

Actual behavior: N

Prediction: Successful

FSM: 0 → 0 (saturated)



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2	2	2	**3 S**			
1	1	1	1	**0 S**	0	**0 S**	0			
2	1	1	1	1	1	1	1			
3	1	1	**0 S**	0	**0 S**	0	0			

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TASK 1 – SOLUTION

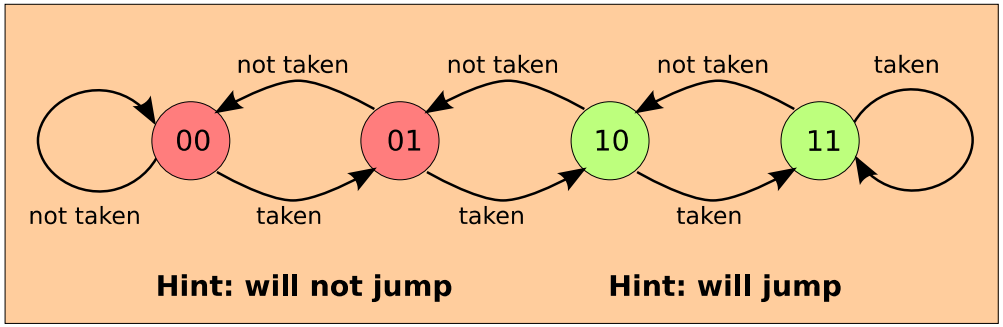
0 (T), 3 (N), 1 (N), 3 (N), 1 (N), 0 (T), **1** (N), 0 (T), 3 (T)

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2	2	2	**3 S**	3		
1	1	1	1	**0 S**	0	**0 S**	0	**0 S**		
2	1	1	1	1	1	1	1	1		
3	1	1	**0 S**	0	**0 S**	0	0	0		

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TASK 1 – SOLUTION

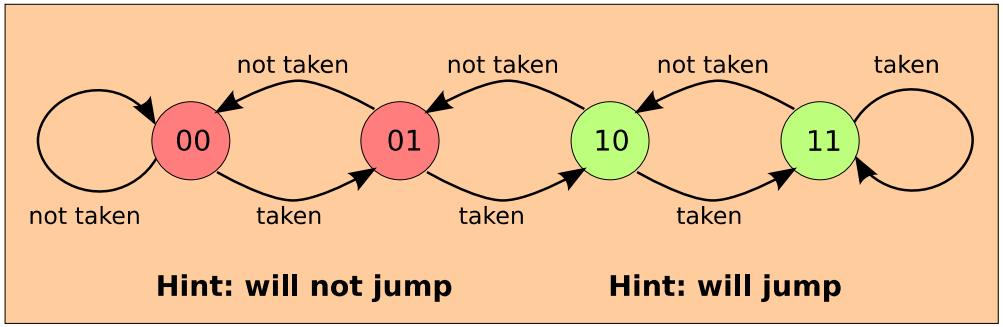
0 (T), 3 (N), 1 (N), 3 (N), 1 (N), 0 (T), 1 (N), **0** (T), 3 (T)

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2	2	2	**3 S**	3		
1	1	1	1	**0 S**	0	**0 S**	0	**0 S**		
2	1	1	1	1	1	1	1	1		
3	1	1	**0 S**	0	**0 S**	0	0	0		

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TASK 1 – SOLUTION

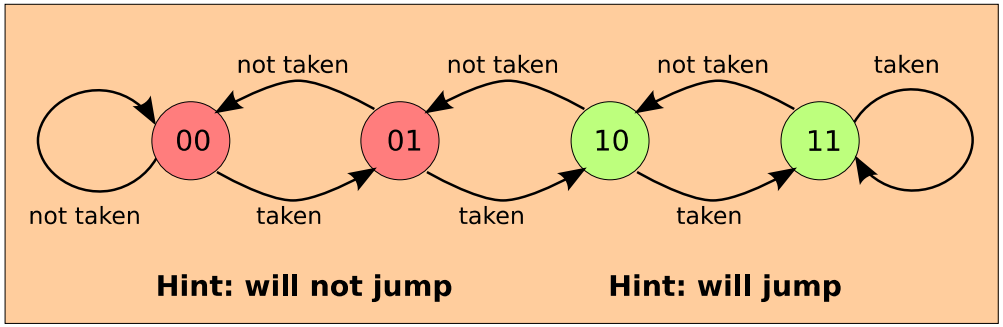
0 (T), 3 (N), 1 (N), 3 (N), 1 (N), 0 (T), 1 (N), **0** (T), 3 (T)

Prediction: will jump

Actual behavior: T

Prediction: Successful

FSM: 3 → 3 (saturated)



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2	2	2	**3 S**	3		
1	1	1	1	**0 S**	0	**0 S**	0	**0 S**		
2	1	1	1	1	1	1	1	1		
3	1	1	**0 S**	0	**0 S**	0	0	0		

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TASK 1 – SOLUTION

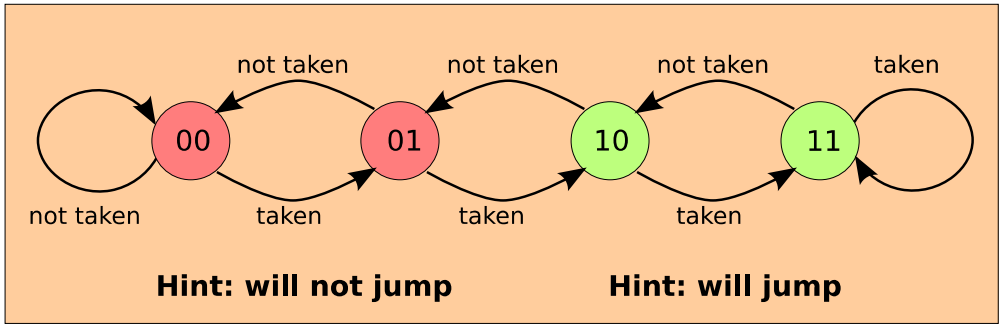
0 (T), 3 (N), 1 (N), 3 (N), 1 (N), 0 (T), 1 (N), **0** (T), 3 (T)

Prediction: will jump

Actual behavior: T

Prediction: Successful

FSM: 3 → 3 (saturated)



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2	2	2	**3 S**	3	**3 S**	
1	1	1	1	**0 S**	0	**0 S**	0	**0 S**	0	
2	1	1	1	1	1	1	1	1	1	
3	1	1	**0 S**	0	**0 S**	0	0	0	0	

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TASK 1 – SOLUTION

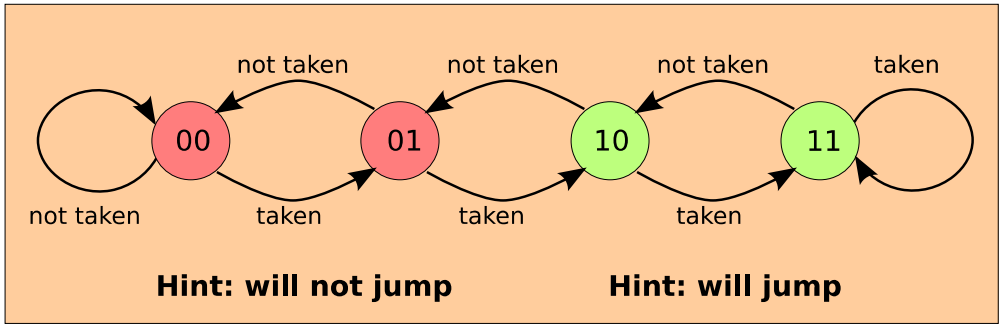
0 (T), 3 (N), 1 (N), 3 (N), 1 (N), 0 (T), 1 (N), 0 (T), **3** (T)

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2	2	2	**3 S**	3	**3 S**	
1	1	1	1	**0 S**	0	**0 S**	0	**0 S**	0	
2	1	1	1	1	1	1	1	1	1	
3	1	1	**0 S**	0	**0 S**	0	0	0	0	

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TASK 1 – SOLUTION

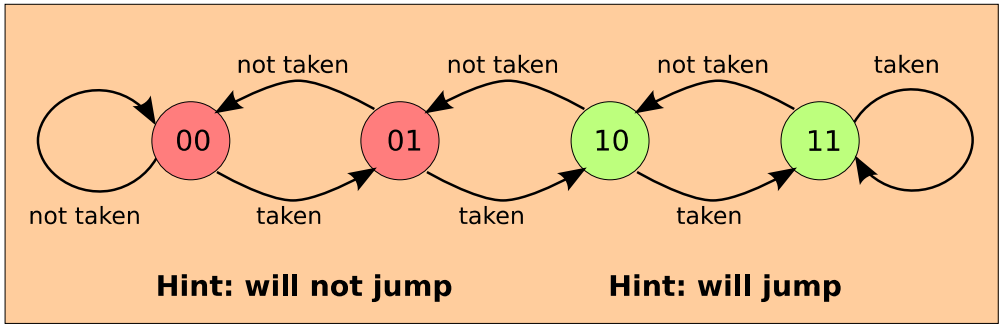
0 (T), 3 (N), 1 (N), 3 (N), 1 (N), 0 (T), 1 (N), 0 (T), **3** (T)

Prediction: will not jump

Actual behavior: T

Prediction: Failed

FSM: 0 → 1



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2	2	2	**3 S**	3	**3 S**	
1	1	1	1	**0 S**	0	**0 S**	0	**0 S**	0	
2	1	1	1	1	1	1	1	1	1	
3	1	1	**0 S**	0	**0 S**	0	0	0	0	

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TASK 1 – SOLUTION

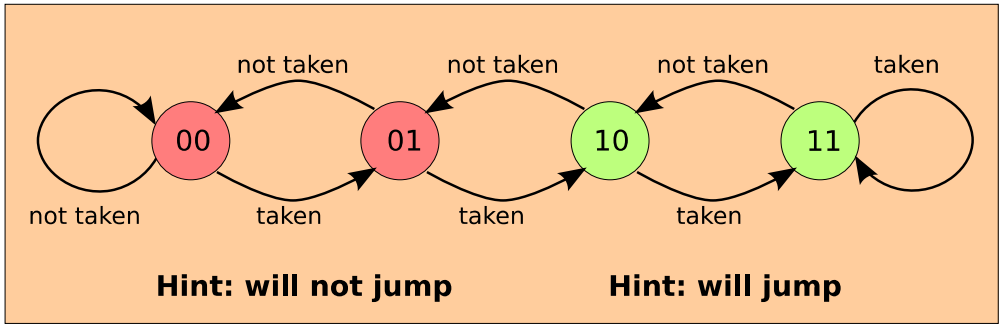
0 (T), 3 (N), 1 (N), 3 (N), 1 (N), 0 (T), 1 (N), 0 (T), **3** (T)

Prediction: will not jump

Actual behavior: T

Prediction: Failed

FSM: 0 → 1



FSM no.	Initial	1	2	3	4	5	6	7	8	9
0	1	**2 F**	2	2	2	2	**3 S**	3	**3 S**	3
1	1	1	1	**0 S**	0	**0 S**	0	**0 S**	0	0
2	1	1	1	1	1	1	1	1	1	1
3	1	1	**0 S**	0	**0 S**	0	0	0	0	**1 F**

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TASK 2 – CORRELATION BASED

- During the execution of a program, the processor evaluates conditional branch instructions located at the following addresses (T: jump is taken, N: jump is not taken):
- 464 (T), 543 (N), 777 (N), 543 (N), 777 (N), 464 (T), 777 (N), 464 (T), 543 (T)
- The processor uses correlation based dynamic branch prediction with PHT containing 2-bit Finite State Machines, and it is able to follow the outcome of the last 2 conditional jump instructions.

  a) How many bits are needed to store the Pattern History Table?

  b) Give the content of the PHT after the execution of every single instruction. Signal, if the prediction of the outcome was successful (S), or failed (F). The initial value of each state machine is 1, and the initial value of the Global Branch History Register is (binary) 11.

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TASK 2 – SOLUTION

a) How many bits are needed to store the Pattern History Table?

- As the processor is able to follow the last 2 conditional jump instructions, its GBHR has 2 bits.
- 2 bits can express 2^2=4 different values
- A 2-bit FSM belongs to each value.
- 4x2=**8** bits are needed to store the PHT.

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TASK 2 – SOLUTION

b) Give the content of the PHT after the execution of every single instruction. Signal, if the prediction of the outcome was successful (S), or failed (F). The initial value of each state machine is 1, and the initial value of the Global Branch History Register is (binary) 11.

- The address of the conditional jump instruction is now redundant.
- 464 (T), 543 (N), 777 (N), 543 (N), 777 (N), 464 (T), 777 (N), 464 (T), 543 (T) → **T, N, N, N, N, T, N, T, T**
- As for the new value of the GBHR, T is represented by 1, and N is represented by 0. The bits enter from the right.

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TASK 2 – SOLUTION

T, N, N, N, N, T, N, T, T

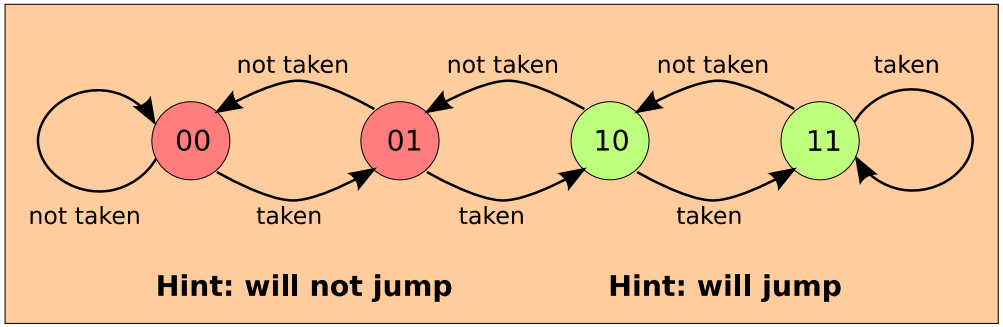
GBHR: 11

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1									
01	1									
10	1									
11	1									

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TASK 2 – SOLUTION

T, N, N, N, N, T, N, T, T

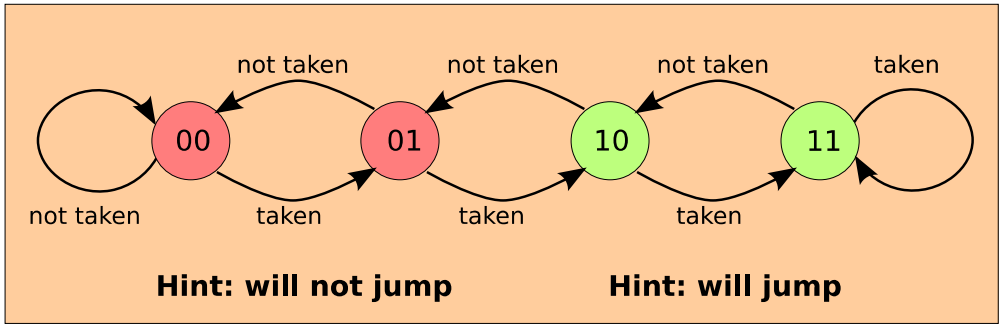
GBHR: 11

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1									
01	1									
10	1									
11	1									

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TASK 2 – SOLUTION

T, N, N, N, N, T, N, T, T

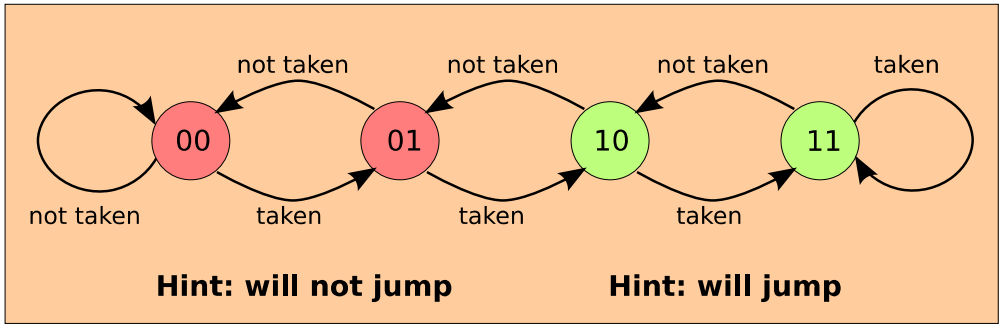
GBHR: 11 → 11

Prediction: will not jump

Actual behavior: T

Prediction: Failed

FSM: 1 → 2



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1									
01	1									
10	1									
11	1									

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TASK 2 – SOLUTION

T, N, N, N, N, T, N, T, T

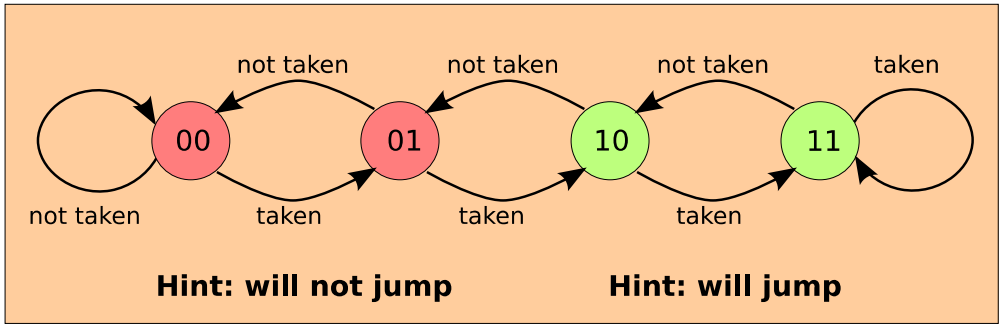
GBHR: 11 → 11

Prediction: will not jump

Actual behavior: T

Prediction: Failed

FSM: 1 → 2



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**								
01	1	1								
10	1	1								
11	1	**2 F**								

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TASK 2 – SOLUTION

T, **N**, N, N, N, T, N, T, T

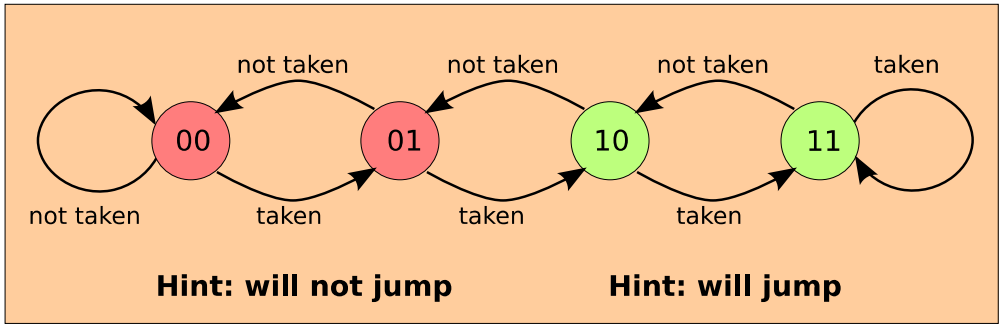
GBHR: 11

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**								
01	1	1								
10	1	1								
11	1	**2 F**								

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TASK 2 – SOLUTION

T, **N**, N, N, N, T, N, T, T

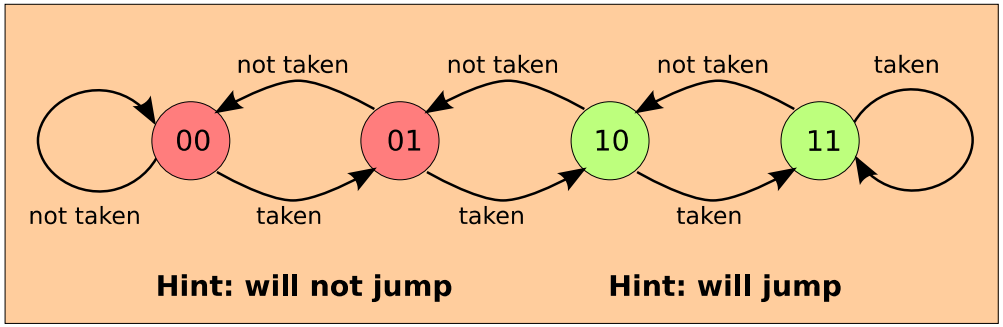
GBHR: 11 → 10

Prediction: will jump

Actual behavior: N

Prediction: Failed

FSM: 2 → 1



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**								
01	1	1								
10	1	1								
11	1	**2 F**								

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TASK 2 – SOLUTION

T, **N**, N, N, N, T, N, T, T

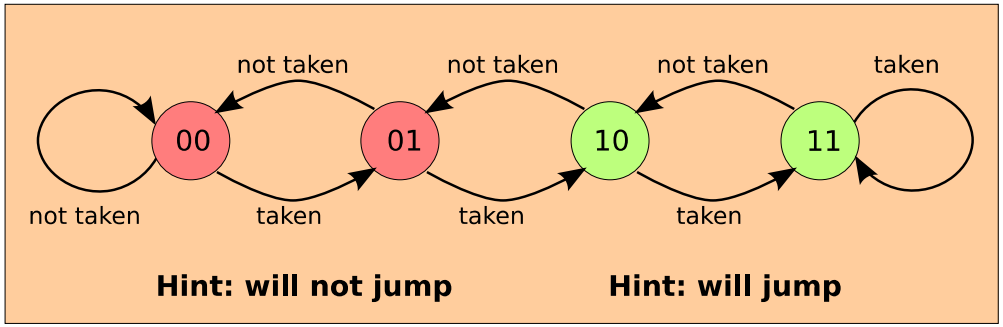
GBHR: 11 → 10

Prediction: will jump

Actual behavior: N

Prediction: Failed

FSM: 2 → 1



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1							
01	1	1	1							
10	1	1	1							
11	1	**2 F**	**1 F**							

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TASK 2 – SOLUTION

T, N, **N**, N, N, T, N, T, T

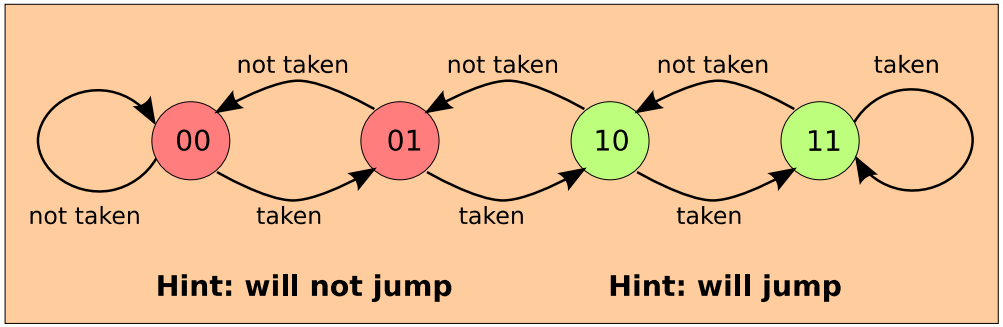
GBHR: 10

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1							
01	1	1	1							
10	1	1	1							
11	1	**2 F**	**1 F**							

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TASK 2 – SOLUTION

T, N, **N**, N, N, T, N, T, T

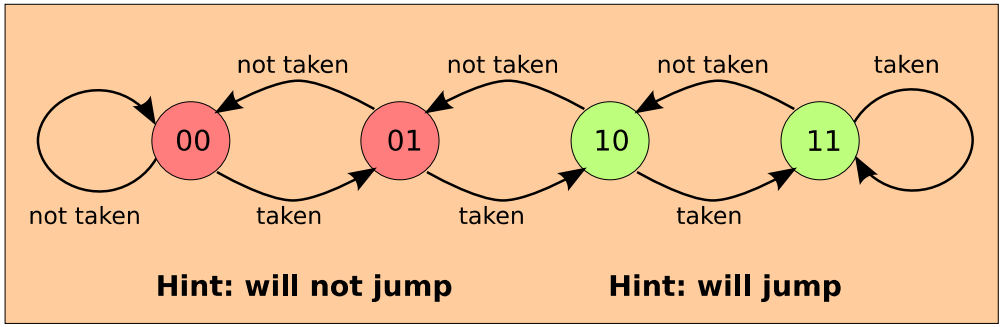
GBHR: 10 → 00

Prediction: will not jump

Actual behavior: N

Prediction: Successful

FSM: 1 → 0



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1							
01	1	1	1							
10	1	1	1							
11	1	**2 F**	**1 F**							

TASK 2 – SOLUTION

T, N, **N**, N, N, T, N, T, T

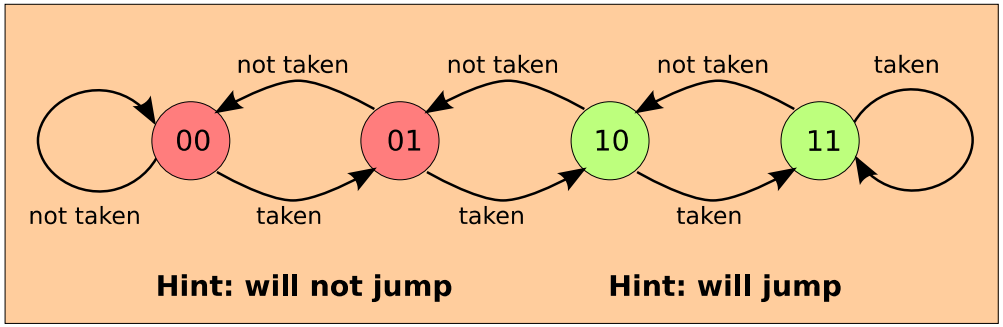
GBHR: 10 → 00

Prediction: will not jump

Actual behavior: N

Prediction: Successful

FSM: 1 → 0



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1						
01	1	1	1	**1**						
10	1	1	1	**0 S**						
11	1	**2 F**	**1 F**	1						

TASK 2 – SOLUTION

T, N, N, **N**, N, T, N, T, T

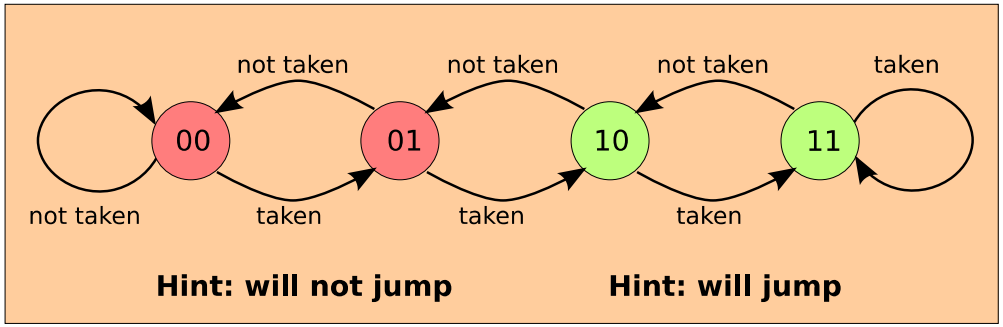
GBHR: 00

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1						
01	1	1	1	**1**						
10	1	1	1	**0 S**						
11	1	**2 F**	**1 F**	1						

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TASK 2 – SOLUTION

T, N, N, **N**, N, T, N, T, T

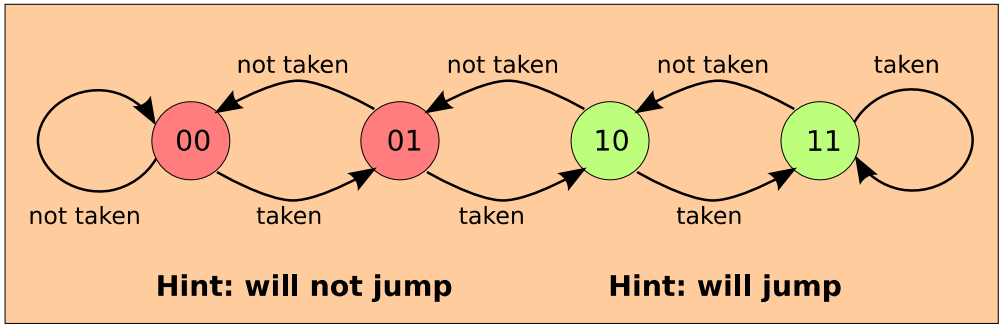
GBHR: 00 → 00

Prediction: will not jump

Actual behavior: N

Prediction: Successful

FSM: 1 → 0



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1						
01	1	1	1	**1**						
10	1	1	1	**0 S**						
11	1	**2 F**	**1 F**	1						

TASK 2 – SOLUTION

T, N, N, **N**, N, T, N, T, T

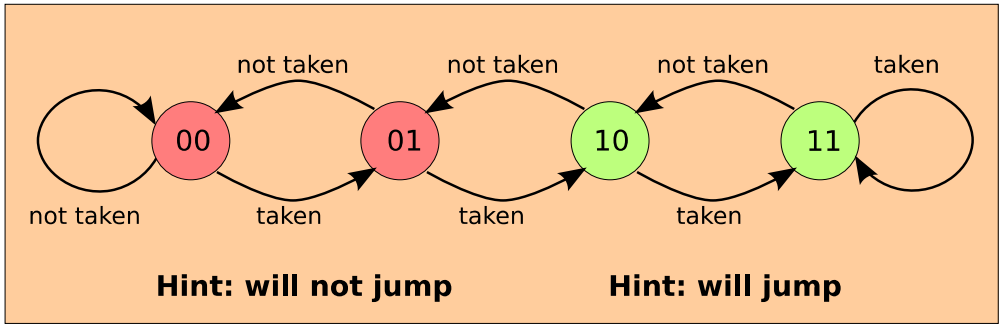
GBHR: 00 → 00

Prediction: will not jump

Actual behavior: N

Prediction: Successful

FSM: 1 → 0



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1	**0 S**					
01	1	1	1	**1**	1					
10	1	1	1	**0 S**	0					
11	1	**2 F**	**1 F**	1	**1**					

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TASK 2 – SOLUTION

T, N, N, N, **N**, T, N, T, T

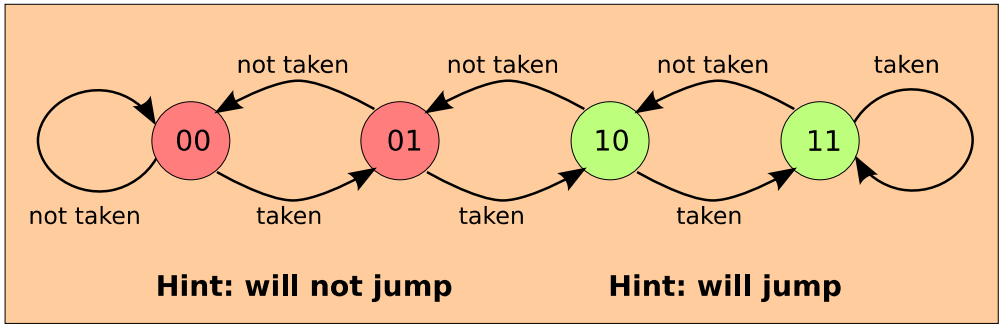
GBHR: 00

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1	**0 S**					
01	1	1	1	**1**	1					
10	1	1	1	**0 S**	0					
11	1	**2 F**	**1 F**	1	**1**					

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TASK 2 – SOLUTION

T, N, N, N, **N**, T, N, T, T

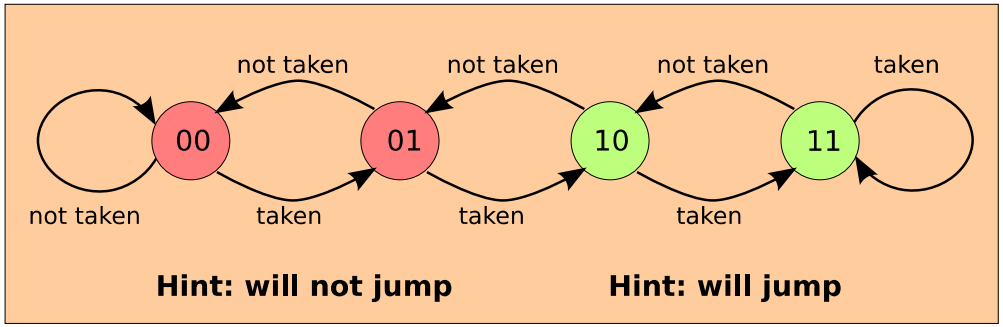
GBHR: 00 → 00

Prediction: will not jump

Actual behavior: N

Prediction: Successful

FSM: 0 → 0 (saturated)



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1	**0 S**					
01	1	1	1	**1**	1					
10	1	1	1	**0 S**	0					
11	1	**2 F**	**1 F**	1	**1**					

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TASK 2 – SOLUTION

T, N, N, N, **N**, T, N, T, T

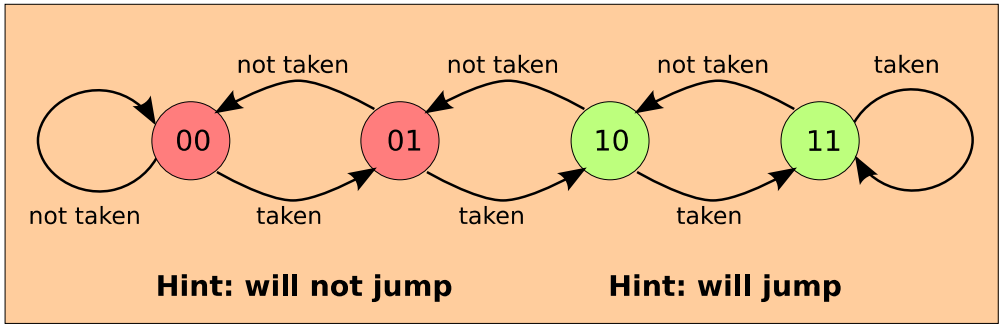
GBHR: 00 → 00

Prediction: will not jump

Actual behavior: N

Prediction: Successful

FSM: 0 → 0 (saturated)



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1	**0 S**	**0 S**				
01	1	1	1	**1**	1	1				
10	1	1	1	**0 S**	0	0				
11	1	**2 F**	**1 F**	1	**1**	1				

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TASK 2 – SOLUTION

T, N, N, N, N, **T**, N, T, T

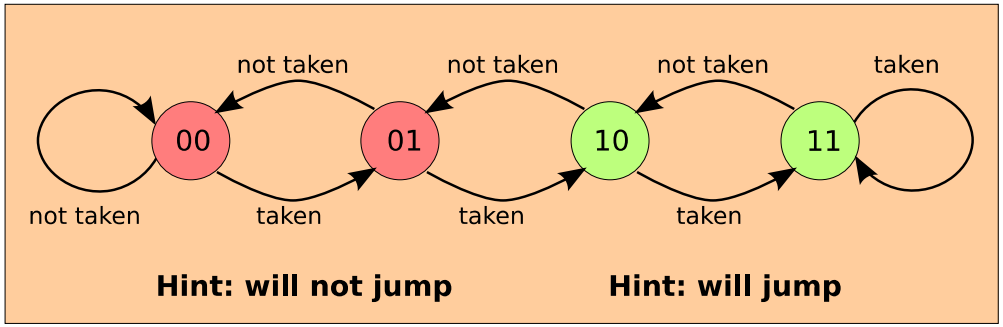
GBHR: 00

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1	**0 S**	**0 S**				
01	1	1	1	**1**	1	1				
10	1	1	1	**0 S**	0	0				
11	1	**2 F**	**1 F**	1	**1**	1				

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TASK 2 – SOLUTION

T, N, N, N, N, **T**, N, T, T

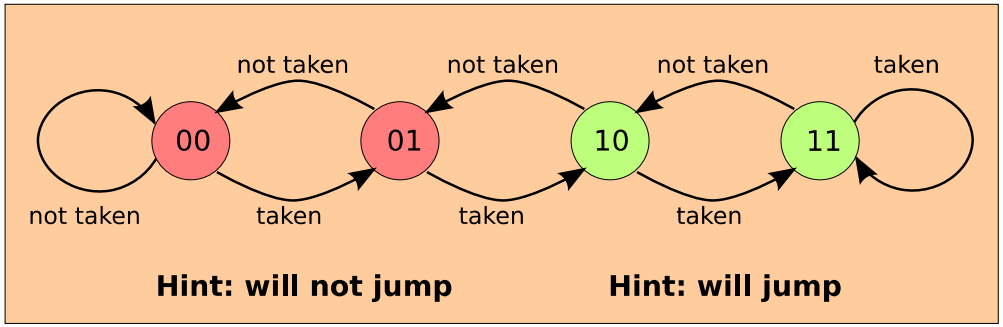
GBHR: 00 → 01

Prediction: will not jump

Actual behavior: T

Prediction: Failed

FSM: 0 → 1



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1	**0 S**	**0 S**				
01	1	1	1	**1**	1	1				
10	1	1	1	**0 S**	0	0				
11	1	**2 F**	**1 F**	1	**1**	1				

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TASK 2 – SOLUTION

T, N, N, N, N, **T**, N, T, T

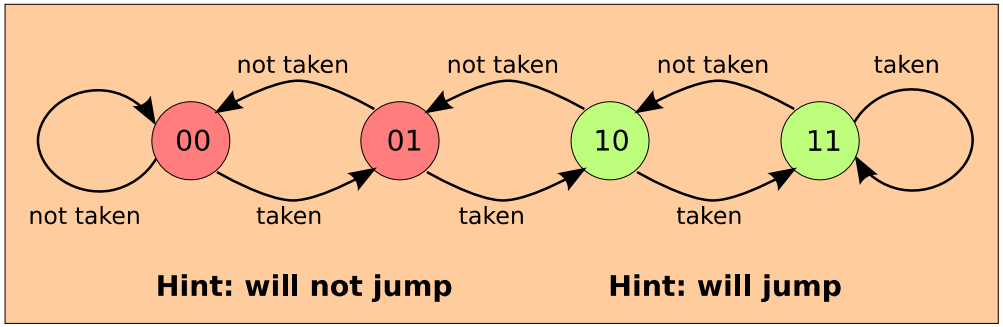
GBHR: 00 → 01

Prediction: will not jump

Actual behavior: T

Prediction: Failed

FSM: 0 → 1



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1	**0 S**	**0 S**	**1 F**			
01	1	1	1	**1**	1	1	1			
10	1	1	1	**0 S**	0	0	0			
11	1	**2 F**	**1 F**	1	**1**	1	1			

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TASK 2 – SOLUTION

T, N, N, N, N, T, **N**, T, T

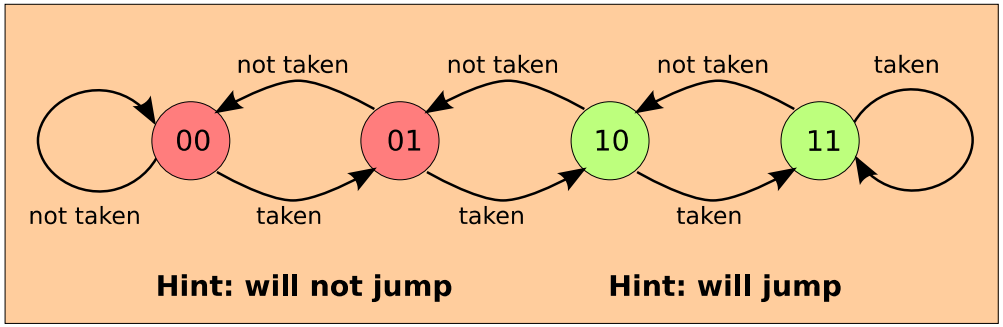
GBHR: 01

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1	**0 S**	**0 S**	**1 F**			
01	1	1	1	**1**	1	1	1			
10	1	1	1	**0 S**	0	0	0			
11	1	**2 F**	**1 F**	1	**1**	1	1			

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TASK 2 – SOLUTION

T, N, N, N, N, T, **N**, T, T

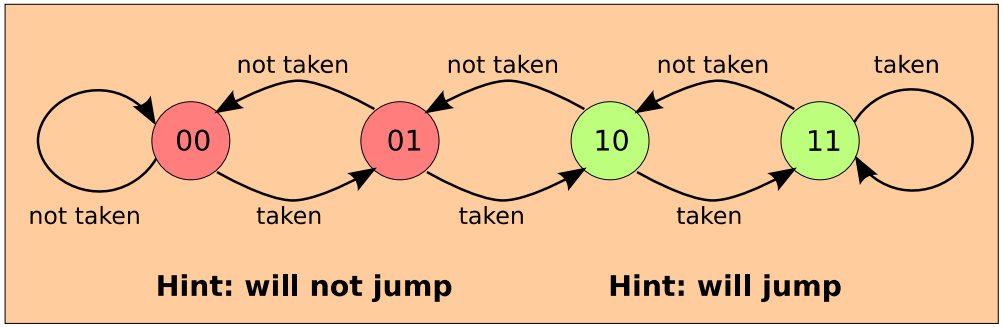
GBHR: 01 → 10

Prediction: will not jump

Actual behavior: N

Prediction: Successful

FSM: 1 → 0



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1	**0 S**	**0 S**	**1 F**			
01	1	1	1	**1**	1	1	1			
10	1	1	1	**0 S**	0	0	0			
11	1	**2 F**	**1 F**	1	**1**	1	1			

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TASK 2 – SOLUTION

T, N, N, N, N, T, **N**, T, T

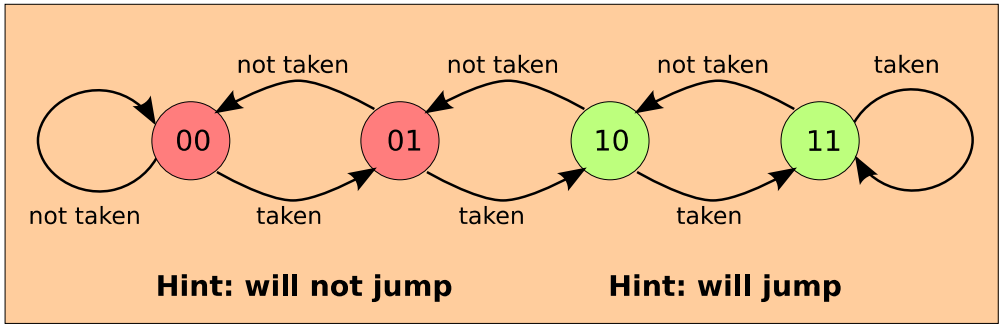
GBHR: 01 → 10

Prediction: will not jump

Actual behavior: N

Prediction: Successful

FSM: 1 → 0



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1	**0 S**	**0 S**	**1 F**	1		
01	1	1	1	**1**	1	1	1	**0 S**		
10	1	1	1	**0 S**	0	0	0	0		
11	1	**2 F**	**1 F**	1	**1**	1	1	1		

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TASK 2 – SOLUTION

T, N, N, N, N, T, N, **T**, T

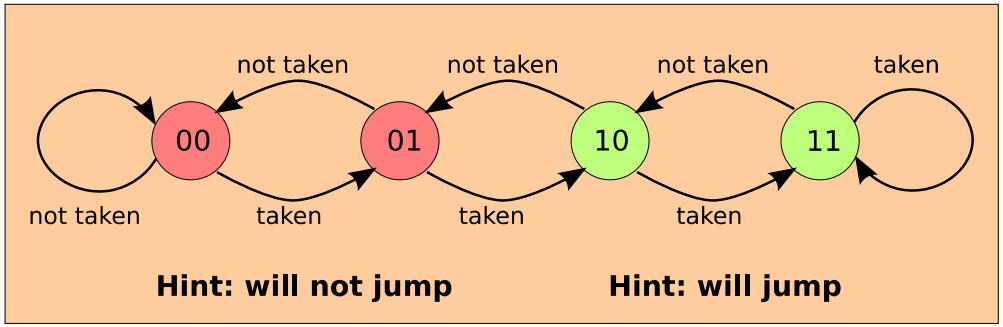
GBHR: 10

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1	**0 S**	**0 S**	**1 F**	1		
01	1	1	1	**1**	1	1	1	**0 S**		
10	1	1	1	**0 S**	0	0	0	0		
11	1	**2 F**	**1 F**	1	**1**	1	1	1		

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TASK 2 – SOLUTION

T, N, N, N, N, T, N, **T**, T

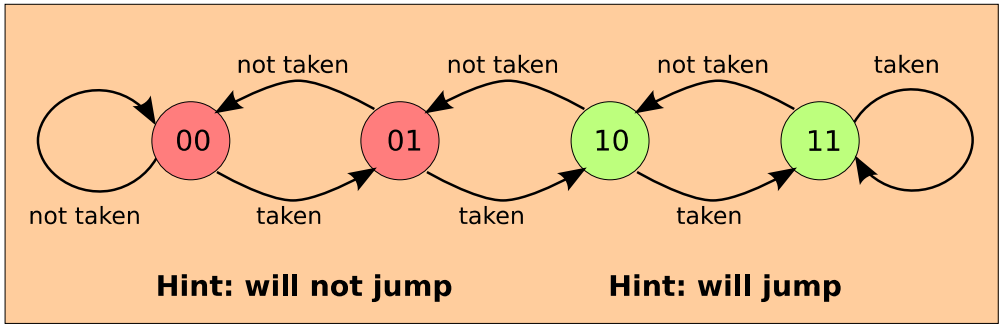
GBHR: 10 → 01

Prediction: will not jump

Actual behavior: T

Prediction: Failed

FSM: 0 → 1



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1	**0 S**	**0 S**	**1 F**	1		
01	1	1	1	**1**	1	1	1	**0 S**		
10	1	1	1	**0 S**	0	0	0	0		
11	1	**2 F**	**1 F**	1	**1**	1	1	1		

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TASK 2 – SOLUTION

T, N, N, N, N, T, N, **T**, T

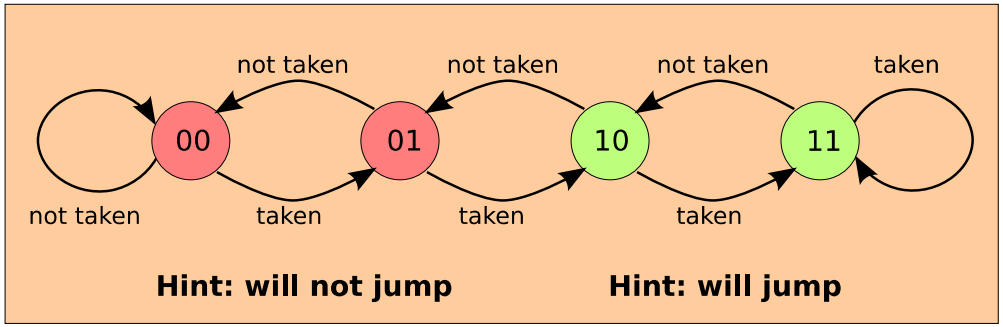
GBHR: 10 → 01

Prediction: will not jump

Actual behavior: T

Prediction: Failed

FSM: 0 → 1



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1	**0 S**	**0 S**	**1 F**	1	1	
01	1	1	1	**1**	1	1	1	**0 S**	0	
10	1	1	1	**0 S**	0	0	0	0	**1 F**	
11	1	**2 F**	**1 F**	1	**1**	1	1	1	1	

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TASK 2 – SOLUTION

T, N, N, N, N, T, N, T, **T**

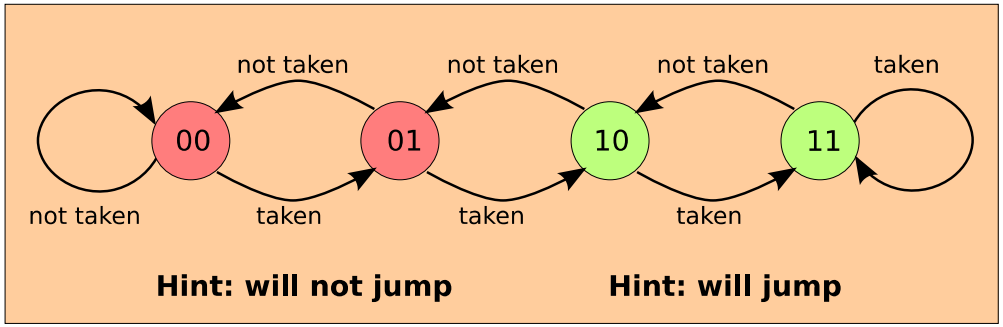
GBHR: 01

Prediction:

Actual behavior:

Prediction:

FSM:



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1	**0 S**	**0 S**	**1 F**	1	1	
01	1	1	1	**1**	1	1	1	**0 S**	0	
10	1	1	1	**0 S**	0	0	0	0	**1 F**	
11	1	**2 F**	**1 F**	1	**1**	1	1	1	1	

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TASK 2 – SOLUTION

T, N, N, N, N, T, N, T, **T**

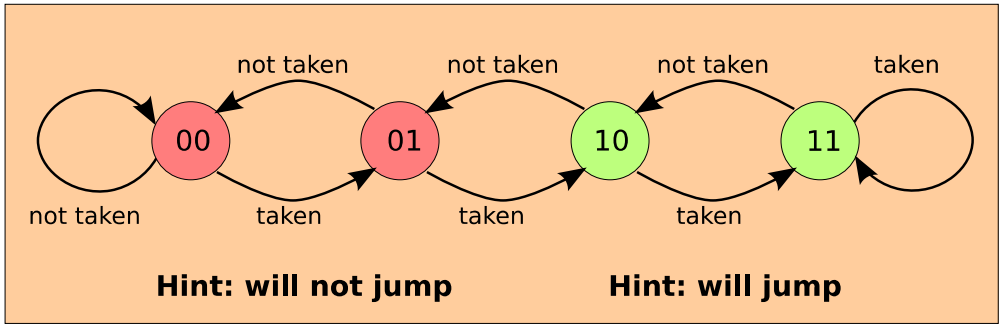
GBHR: 01 → 11

Prediction: will not jump

Actual behavior: T

Prediction: Failed

FSM: 0 → 1



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1	**0 S**	**0 S**	**1 F**	1	1	
01	1	1	1	**1**	1	1	1	**0 S**	0	
10	1	1	1	**0 S**	0	0	0	0	**1 F**	
11	1	**2 F**	**1 F**	1	**1**	1	1	1	1	

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TASK 2 – SOLUTION

T, N, N, N, N, T, N, T, **T**

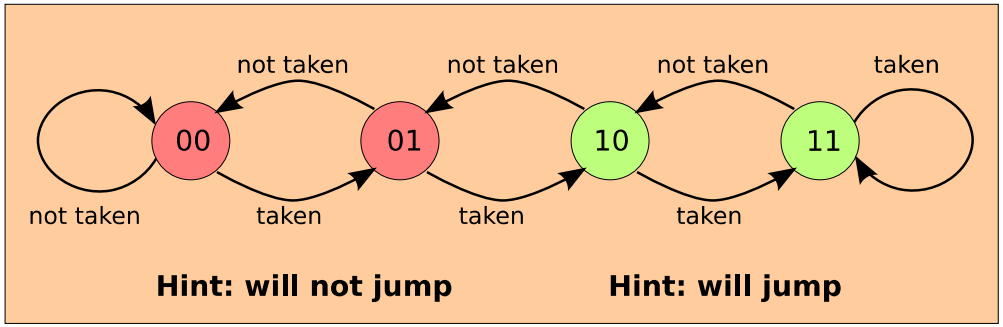
GBHR: 01 → 11

Prediction: will not jump

Actual behavior: T

Prediction: Failed

FSM: 0 → 1



FSM no.	Initial	1	2	3	4	5	6	7	8	9
00	1	**1**	1	1	**0 S**	**0 S**	**1 F**	1	1	1
01	1	1	1	**1**	1	1	1	**0 S**	0	**1 F**
10	1	1	1	**0 S**	0	0	0	0	**1 F**	1
11	1	**2 F**	**1 F**	1	**1**	1	1	1	1	1

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