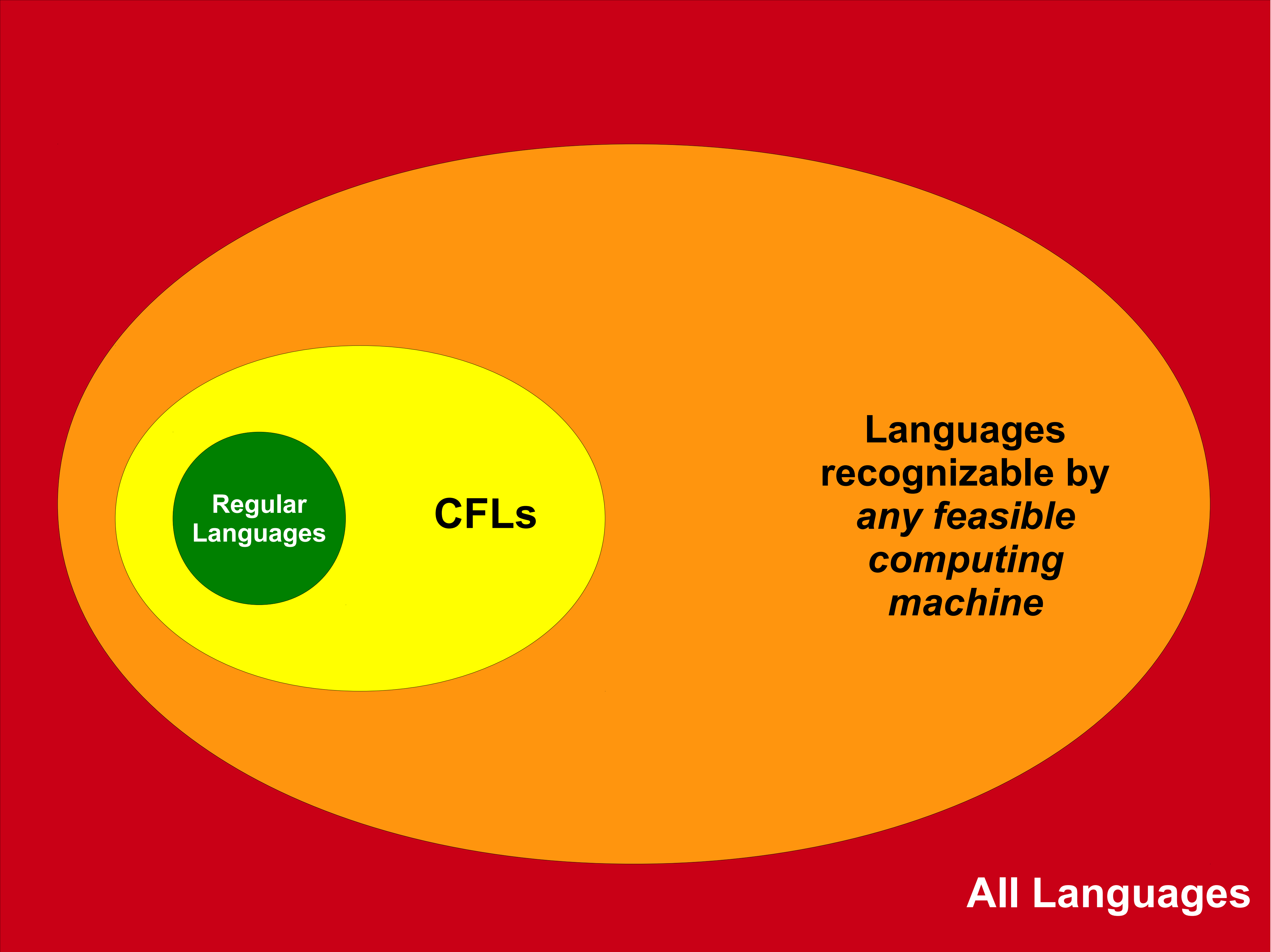
Turing Machines

Part One

What problems can we solve with a computer?



Regular Languages

CFLs

Languages recognizable by *any feasible computing machine*

All Languages

That same drawing, to scale.

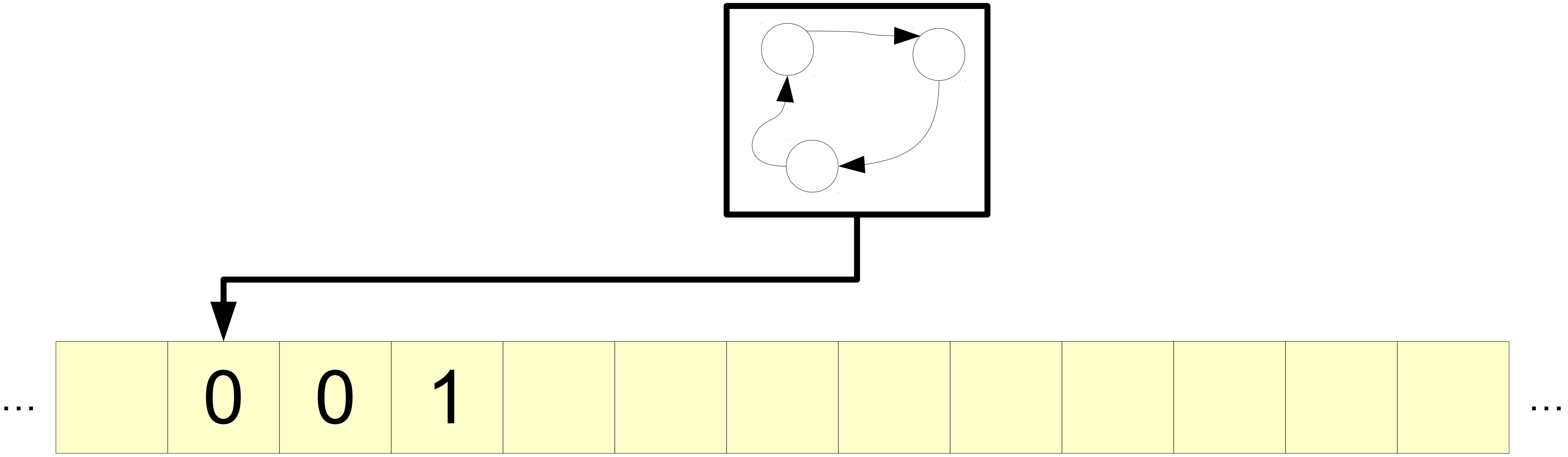
The Problem

- Finite automata accept precisely the regular languages.
- We may need unbounded memory to recognize context-free languages.
  - e.g. $\{ \mathtt{a}^n\mathtt{b}^n \mid n \in \mathbb{N} \}$ requires unbounded counting.
- How do we build an automaton with finitely many states but unbounded memory?

A Brief History Lesson

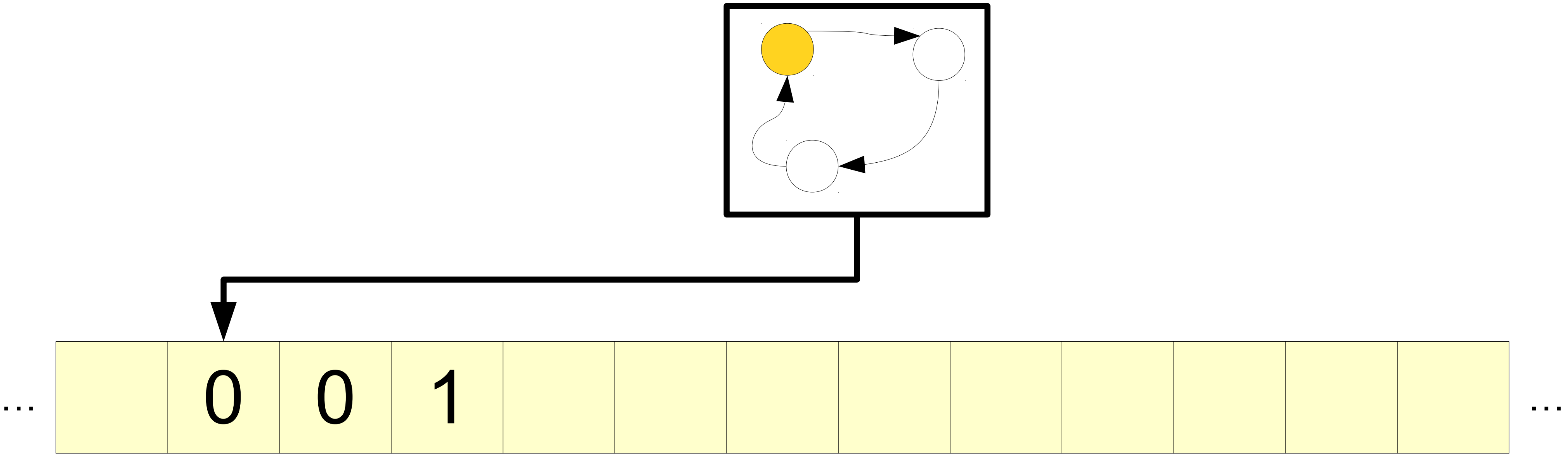
A Better Memory Device

- A ***Turing machine*** is a deterministic finite automaton equipped with an ***infinite tape*** as its memory.
- The input is written on the tape when the computation begins, surrounded by infinitely many blank cells.
- Each transition depends on the current symbol under the tape head.



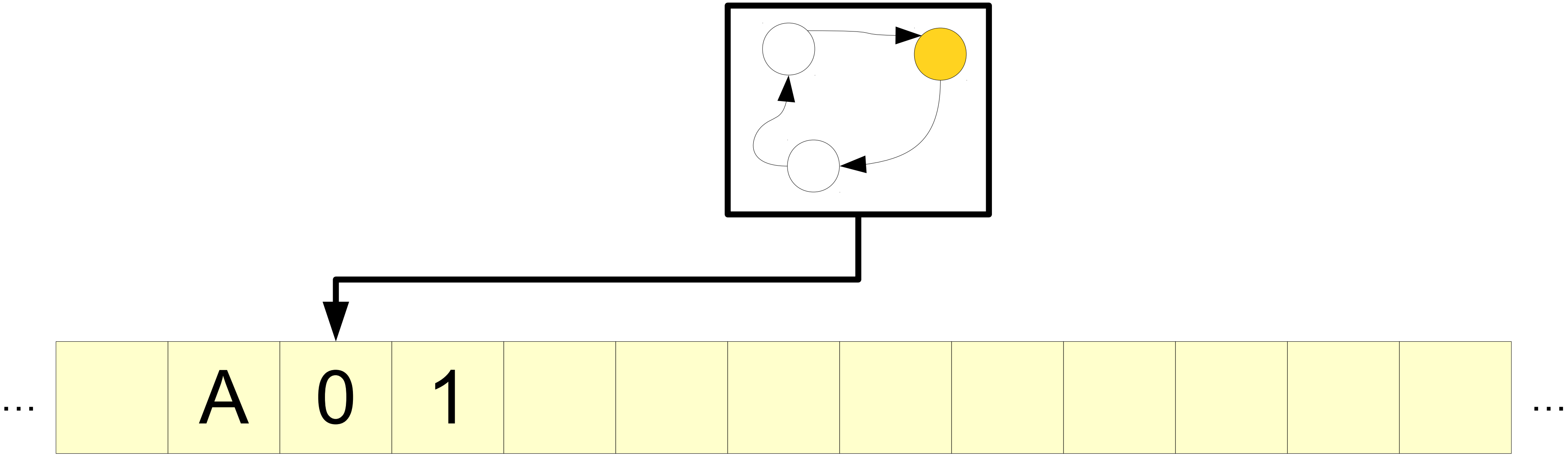
A Better Memory Device

- A ***Turing machine*** is a deterministic finite automaton equipped with an ***infinite tape*** as its memory.
- The input is written on the tape when the computation begins, surrounded by infinitely many blank cells.
- Each transition depends on the current symbol under the tape head.



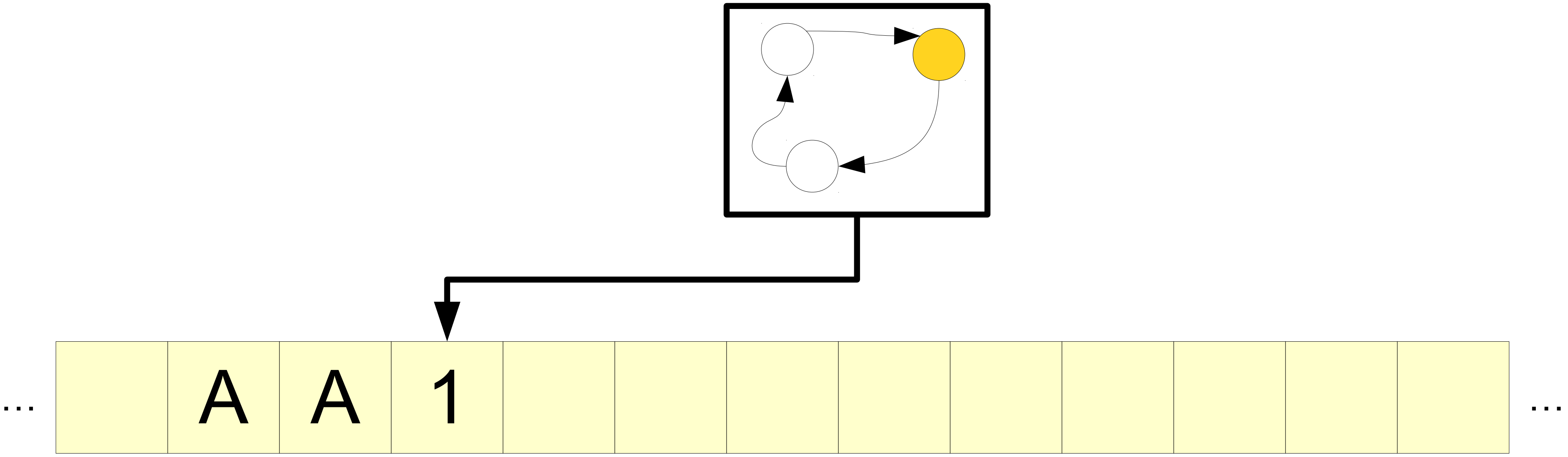
A Better Memory Device

- A ***Turing machine*** is a deterministic finite automaton equipped with an ***infinite tape*** as its memory.
- The input is written on the tape when the computation begins, surrounded by infinitely many blank cells.
- Each transition depends on the current symbol under the tape head.



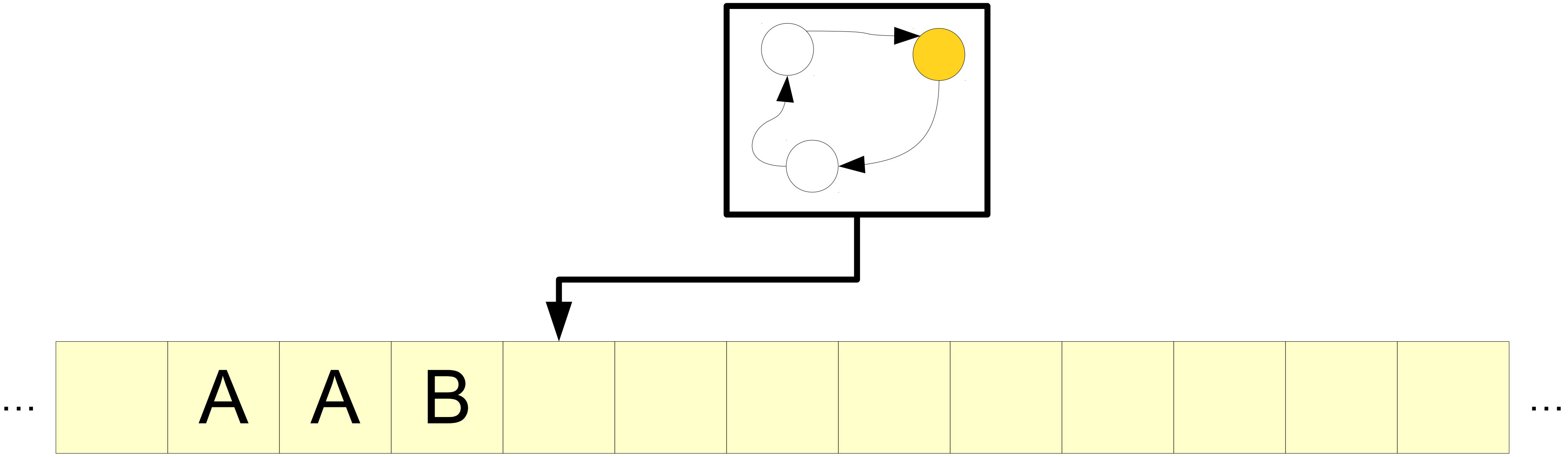
A Better Memory Device

- A ***Turing machine*** is a deterministic finite automaton equipped with an ***infinite tape*** as its memory.
- The input is written on the tape when the computation begins, surrounded by infinitely many blank cells.
- Each transition depends on the current symbol under the tape head.



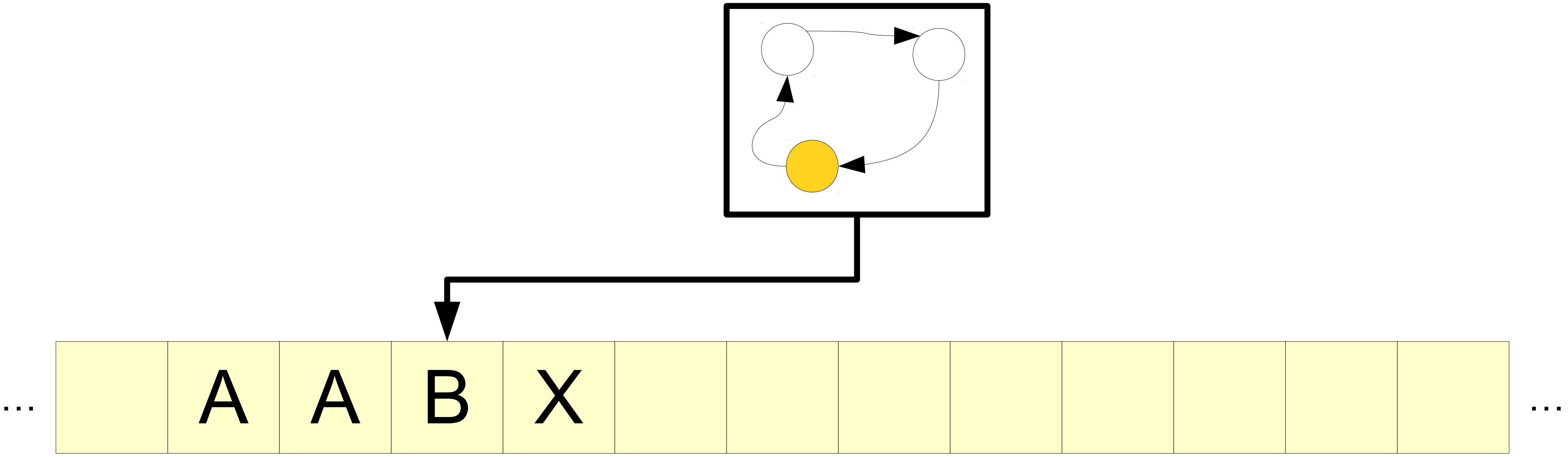
A Better Memory Device

- A ***Turing machine*** is a deterministic finite automaton equipped with an ***infinite tape*** as its memory.
- The input is written on the tape when the computation begins, surrounded by infinitely many blank cells.
- Each transition depends on the current symbol under the tape head.



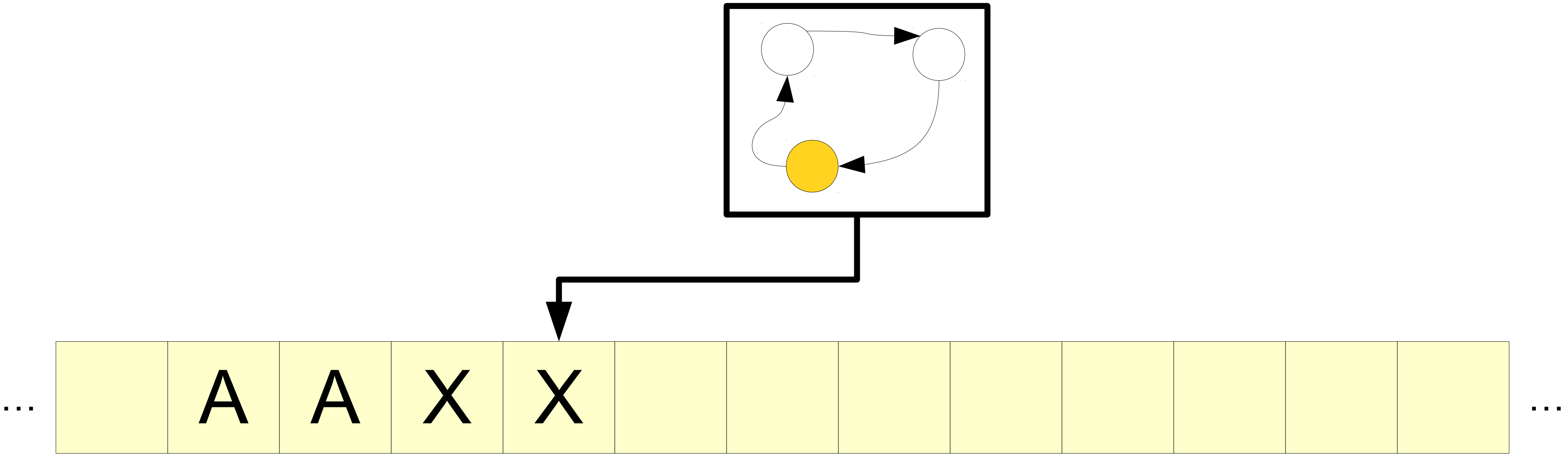
A Better Memory Device

- A ***Turing machine*** is a deterministic finite automaton equipped with an ***infinite tape*** as its memory.
- The input is written on the tape when the computation begins, surrounded by infinitely many blank cells.
- Each transition depends on the current symbol under the tape head.



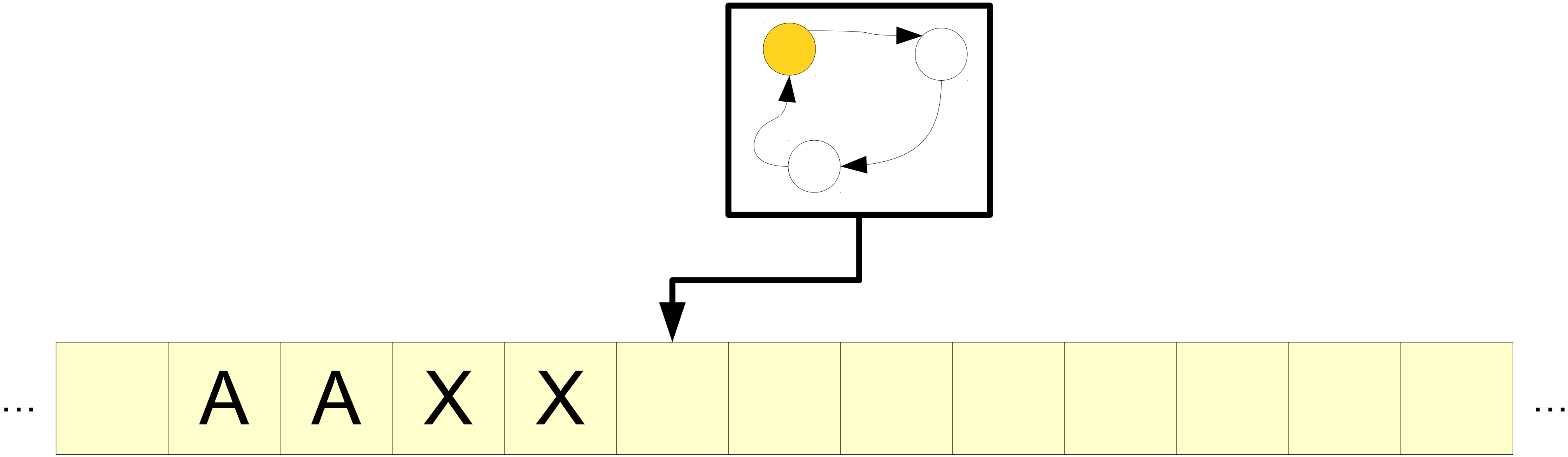
A Better Memory Device

- A ***Turing machine*** is a deterministic finite automaton equipped with an ***infinite tape*** as its memory.
- The input is written on the tape when the computation begins, surrounded by infinitely many blank cells.
- Each transition depends on the current symbol under the tape head.



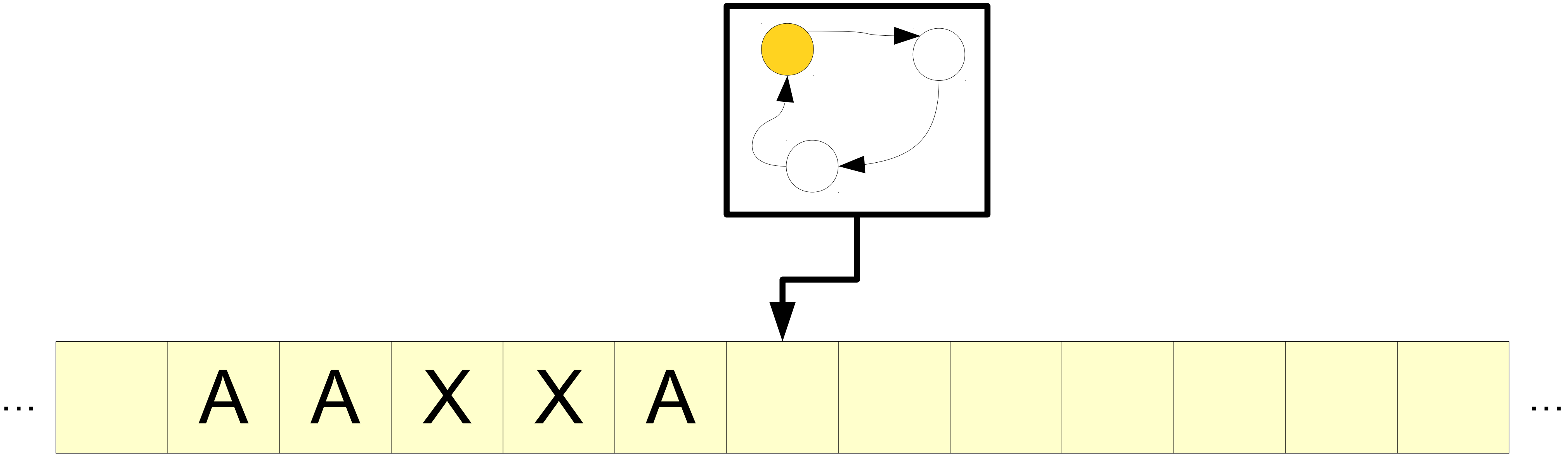
A Better Memory Device

- A ***Turing machine*** is a deterministic finite automaton equipped with an ***infinite tape*** as its memory.
- The input is written on the tape when the computation begins, surrounded by infinitely many blank cells.
- Each transition depends on the current symbol under the tape head.



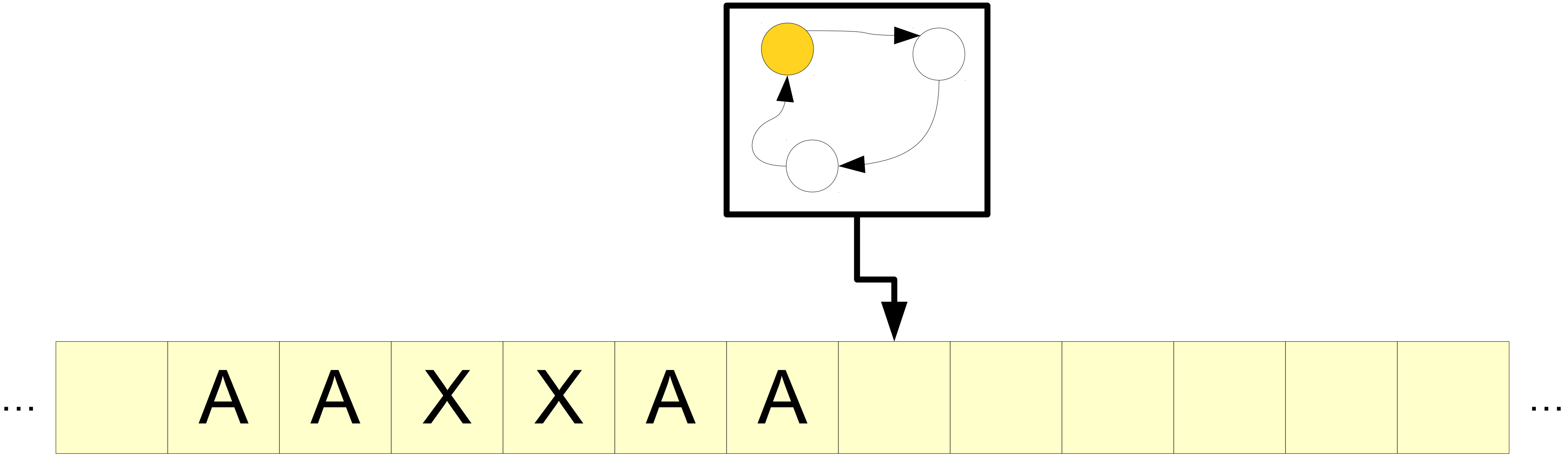
A Better Memory Device

- A ***Turing machine*** is a deterministic finite automaton equipped with an ***infinite tape*** as its memory.
- The input is written on the tape when the computation begins, surrounded by infinitely many blank cells.
- Each transition depends on the current symbol under the tape head.



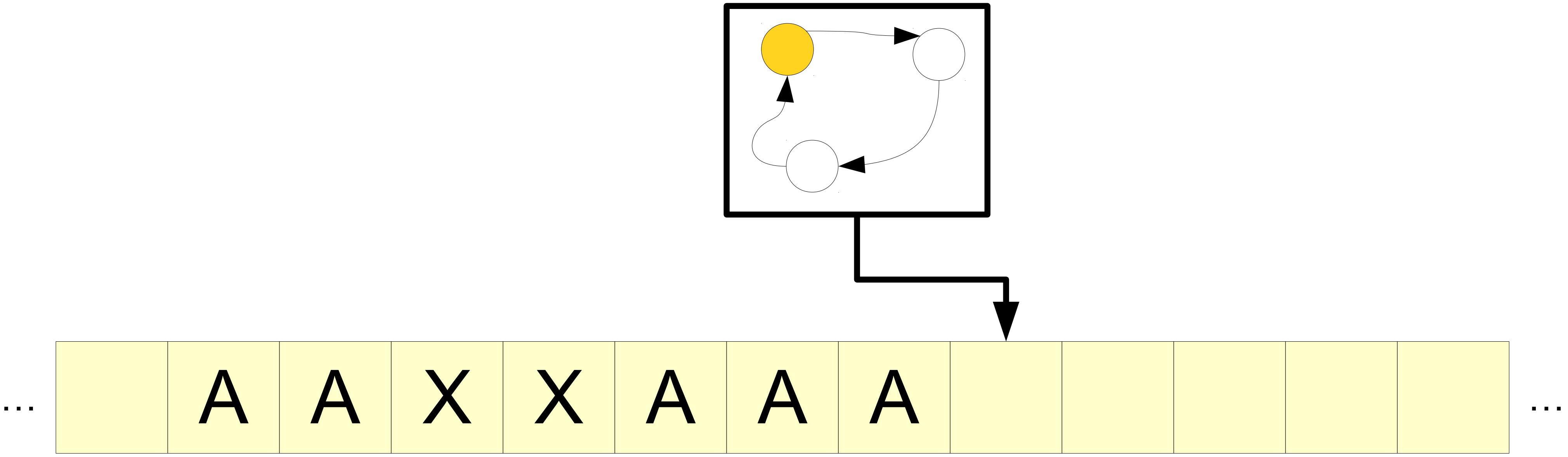
A Better Memory Device

- A ***Turing machine*** is a deterministic finite automaton equipped with an ***infinite tape*** as its memory.
- The input is written on the tape when the computation begins, surrounded by infinitely many blank cells.
- Each transition depends on the current symbol under the tape head.



A Better Memory Device

- A ***Turing machine*** is a deterministic finite automaton equipped with an ***infinite tape*** as its memory.
- The input is written on the tape when the computation begins, surrounded by infinitely many blank cells.
- Each transition depends on the current symbol under the tape head.



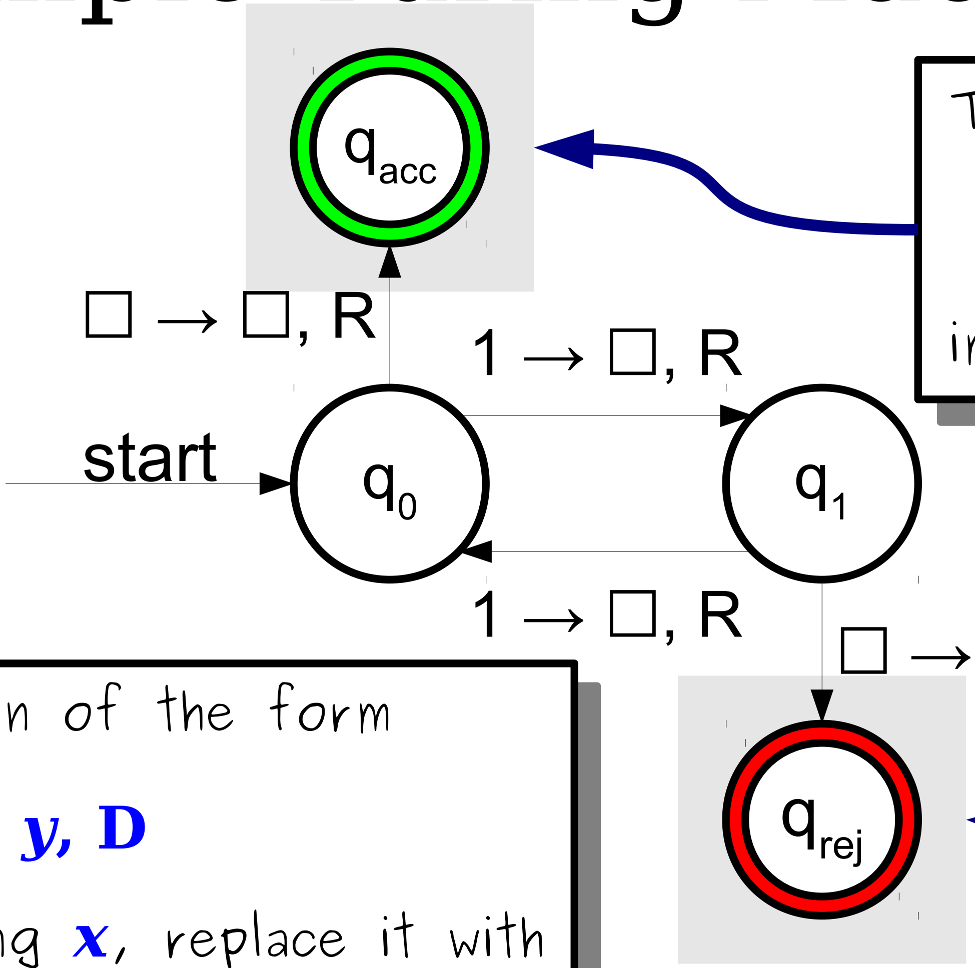
The Turing Machine

- A Turing machine consists of three parts:
  - A ***finite-state control*** that issues commands,
  - an ***infinite tape*** for input and scratch space, and
  - a ***tape head*** that can read and write a single tape cell.
- At each step, the Turing machine
  - writes a symbol to the tape cell under the tape head,
  - changes state, and
  - moves the tape head to the left or to the right.

Input and Tape Alphabets

- A Turing machine has two alphabets:
  - An ***input alphabet*** Σ. All input strings are written in the input alphabet.
  - A ***tape alphabet*** Γ, where Σ ⊆ Γ. The tape alphabet contains all symbols that can be written onto the tape.
- The tape alphabet Γ can contain any number of symbols, but always contains at least one ***blank symbol***, denoted ☐. You are guaranteed ☐ ∉ Σ.
- At startup, the Turing machine begins with an infinite tape of ☐ symbols with the input written at some location. The tape head is positioned at the start of the input.

A Simple Turing Machine



This special **accept state** causes the machine to immediately accept.

This special **reject state** causes the machine to immediately reject.

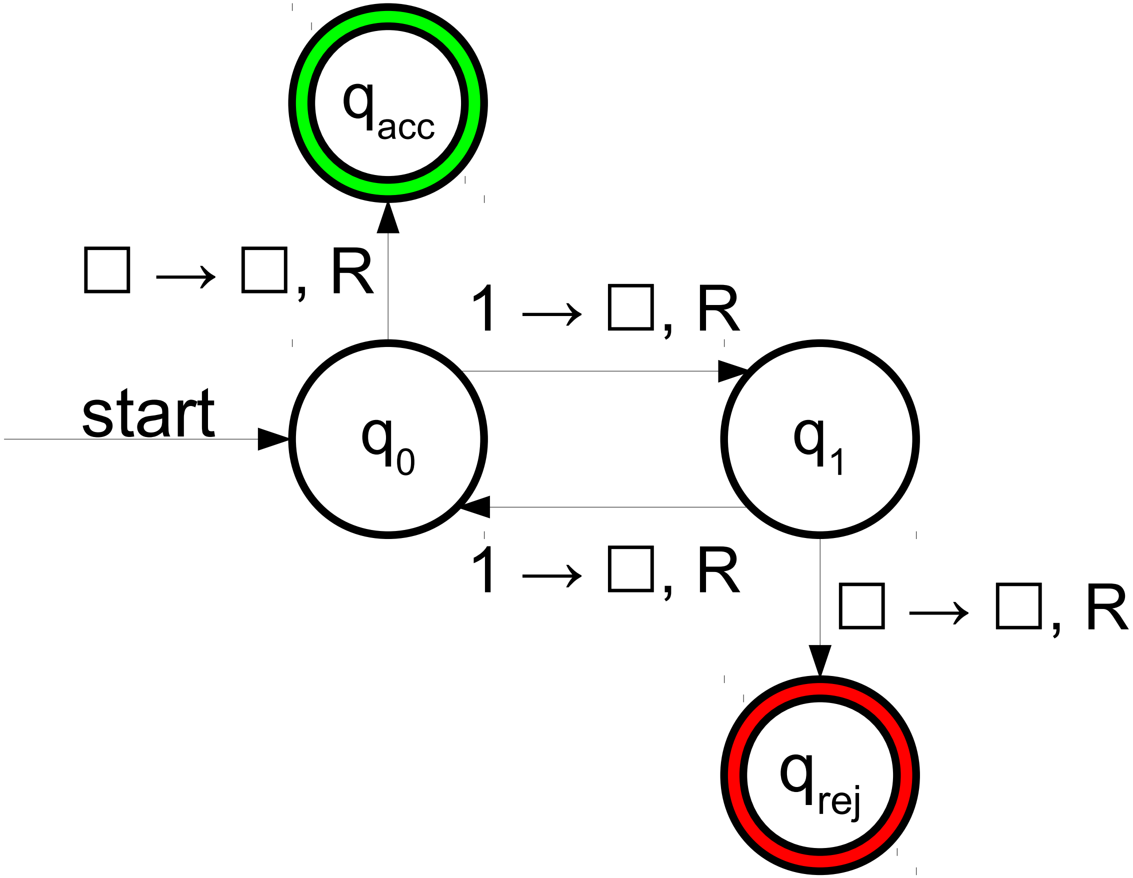
Each transition of the form

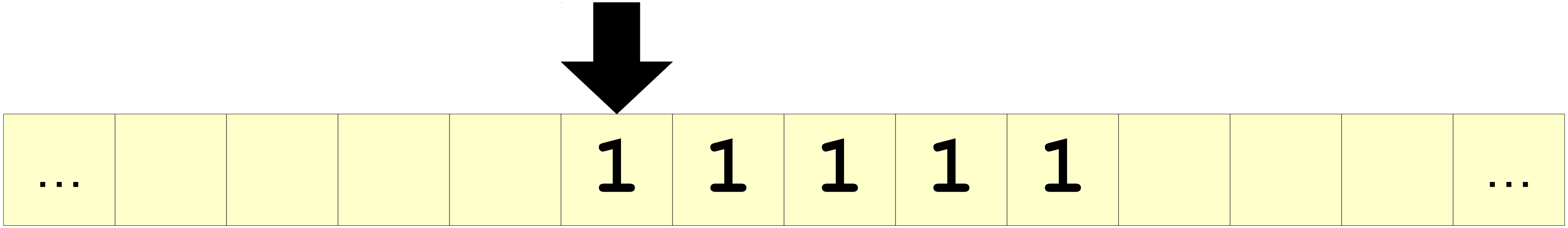
***x* → *y*, D**

means "upon reading ***x***, replace it with symbol ***y*** and move the tape head in direction **D** (which is either **L** or **R**).

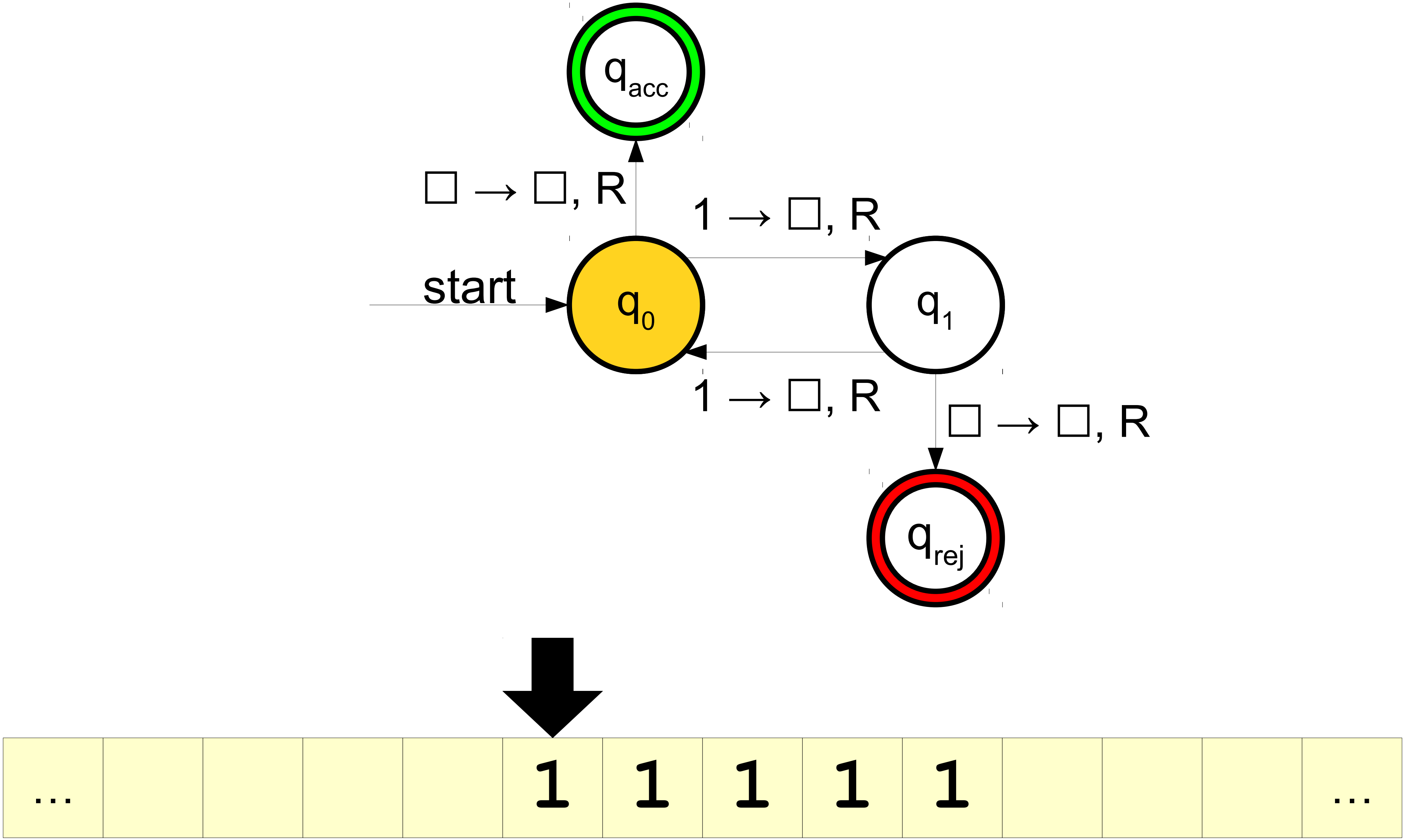
The symbol □ represents the **blank symbol**.

A Simple Turing Machine

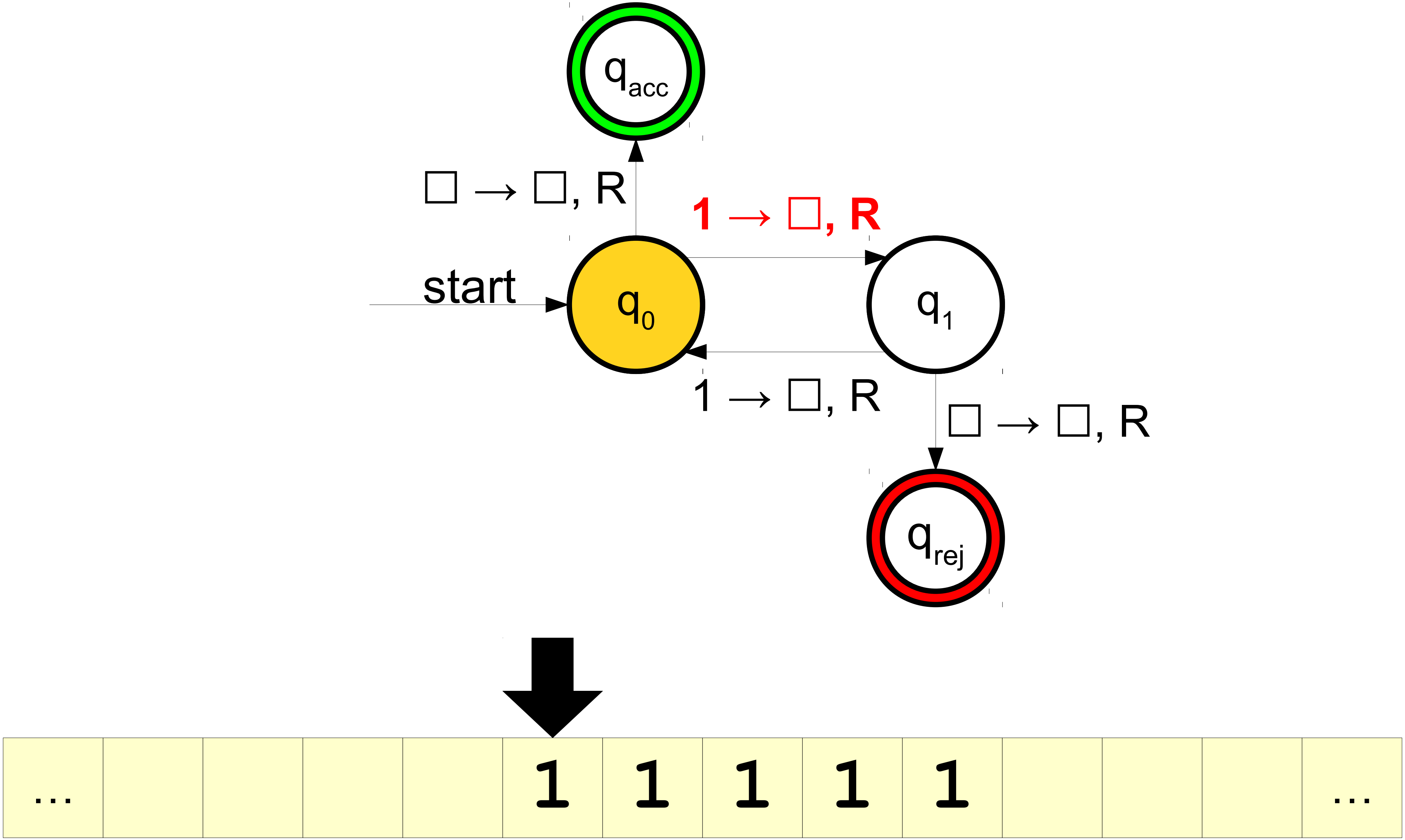




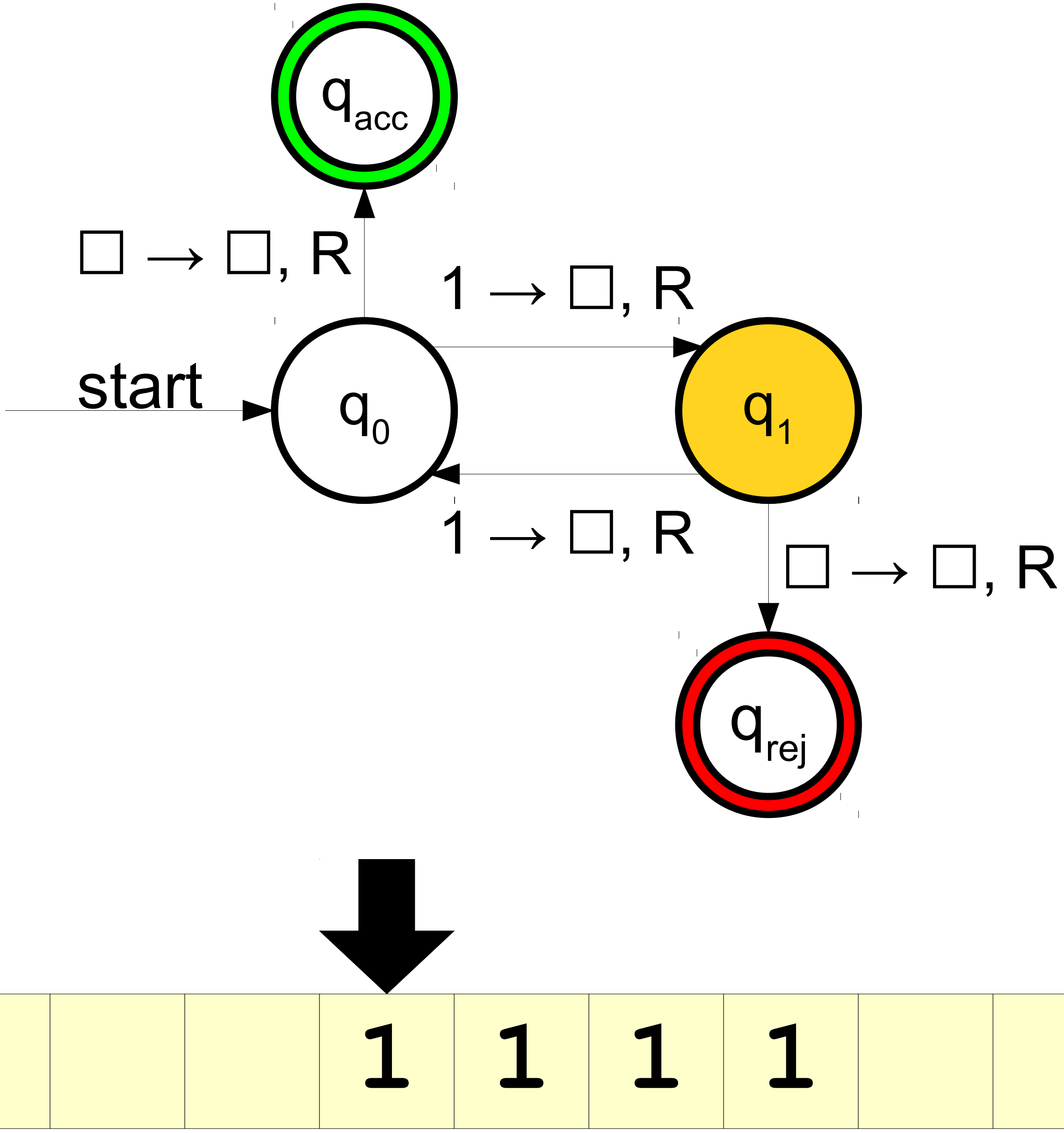
A Simple Turing Machine



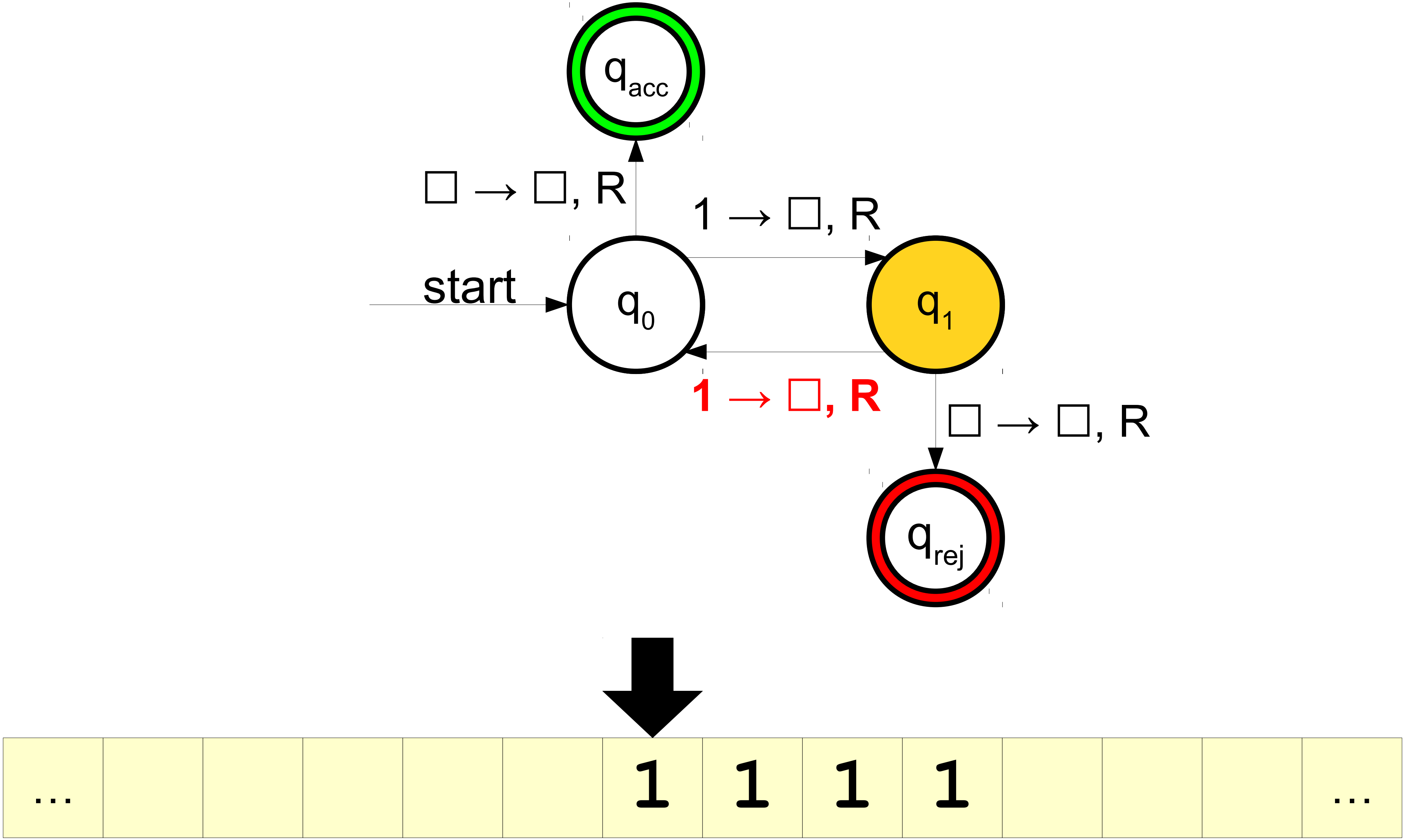
A Simple Turing Machine



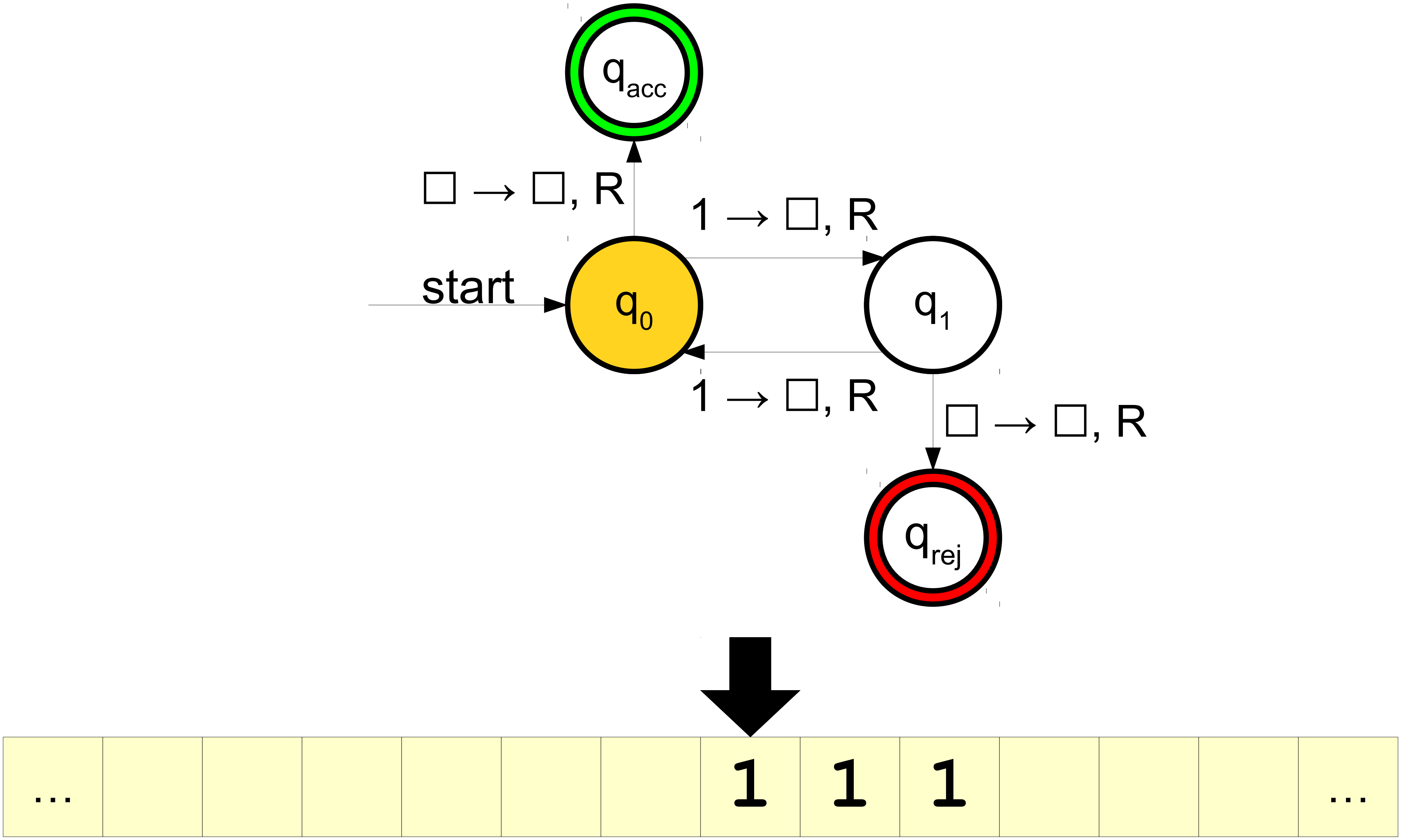
A Simple Turing Machine



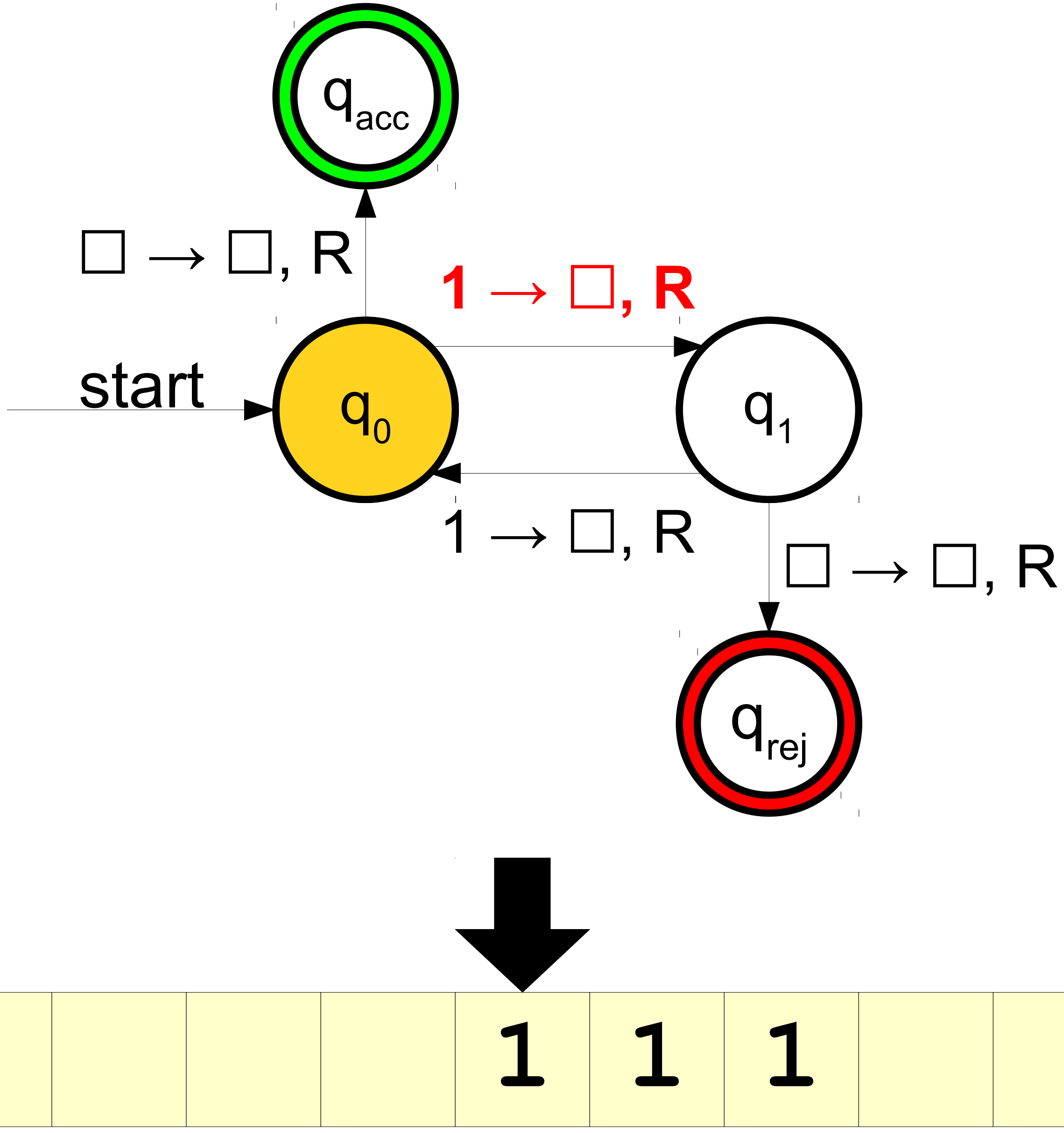
A Simple Turing Machine



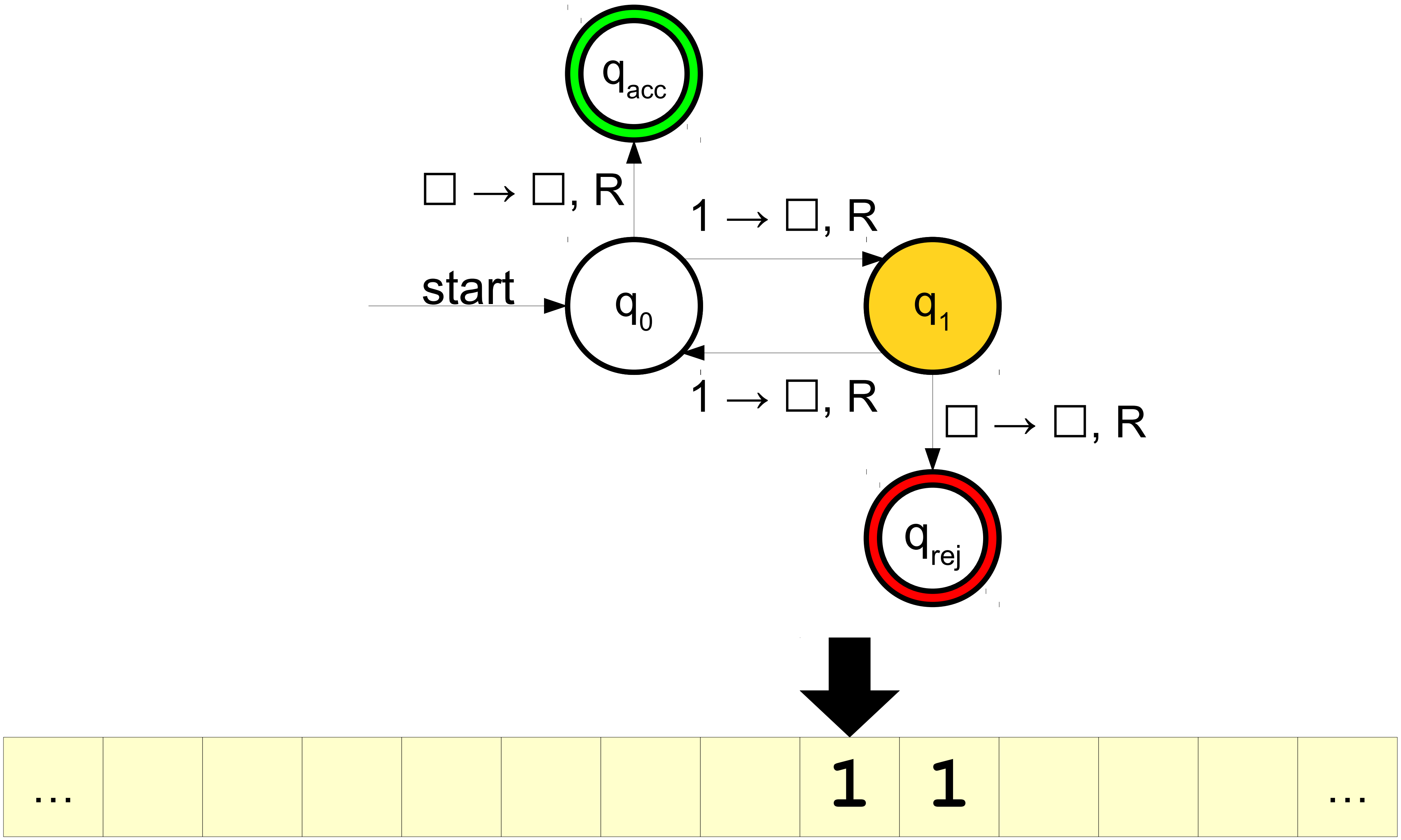
A Simple Turing Machine



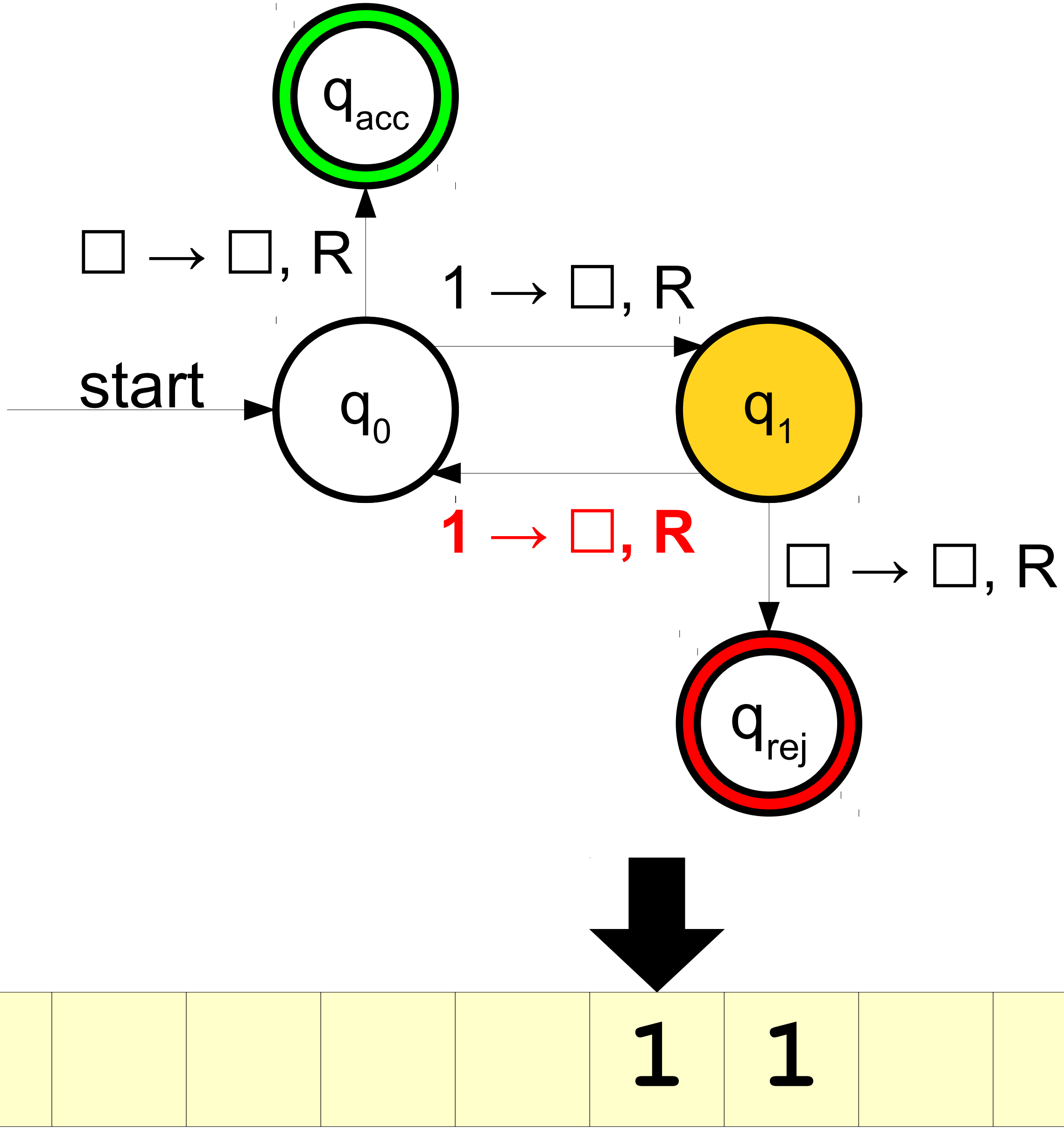
A Simple Turing Machine



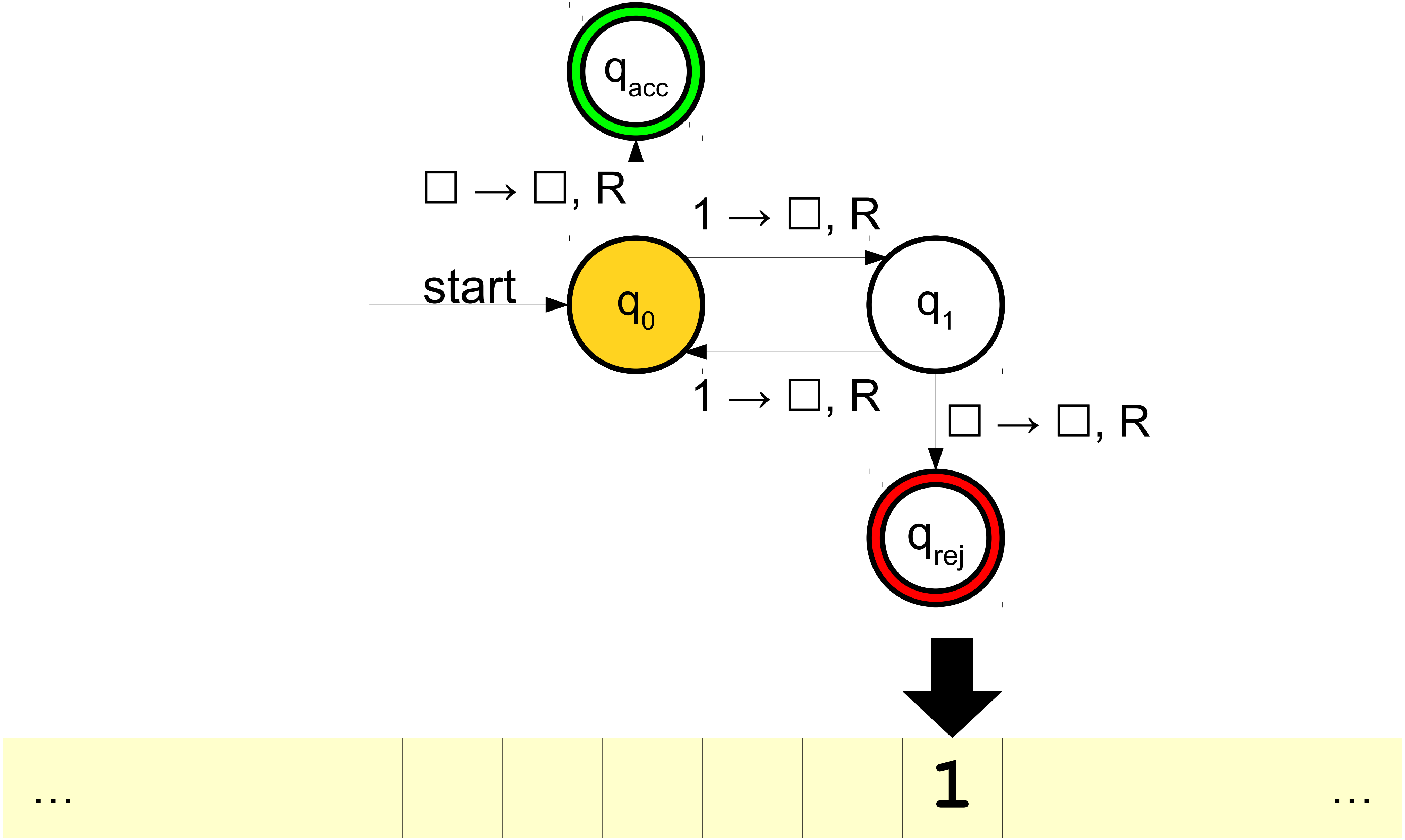
A Simple Turing Machine



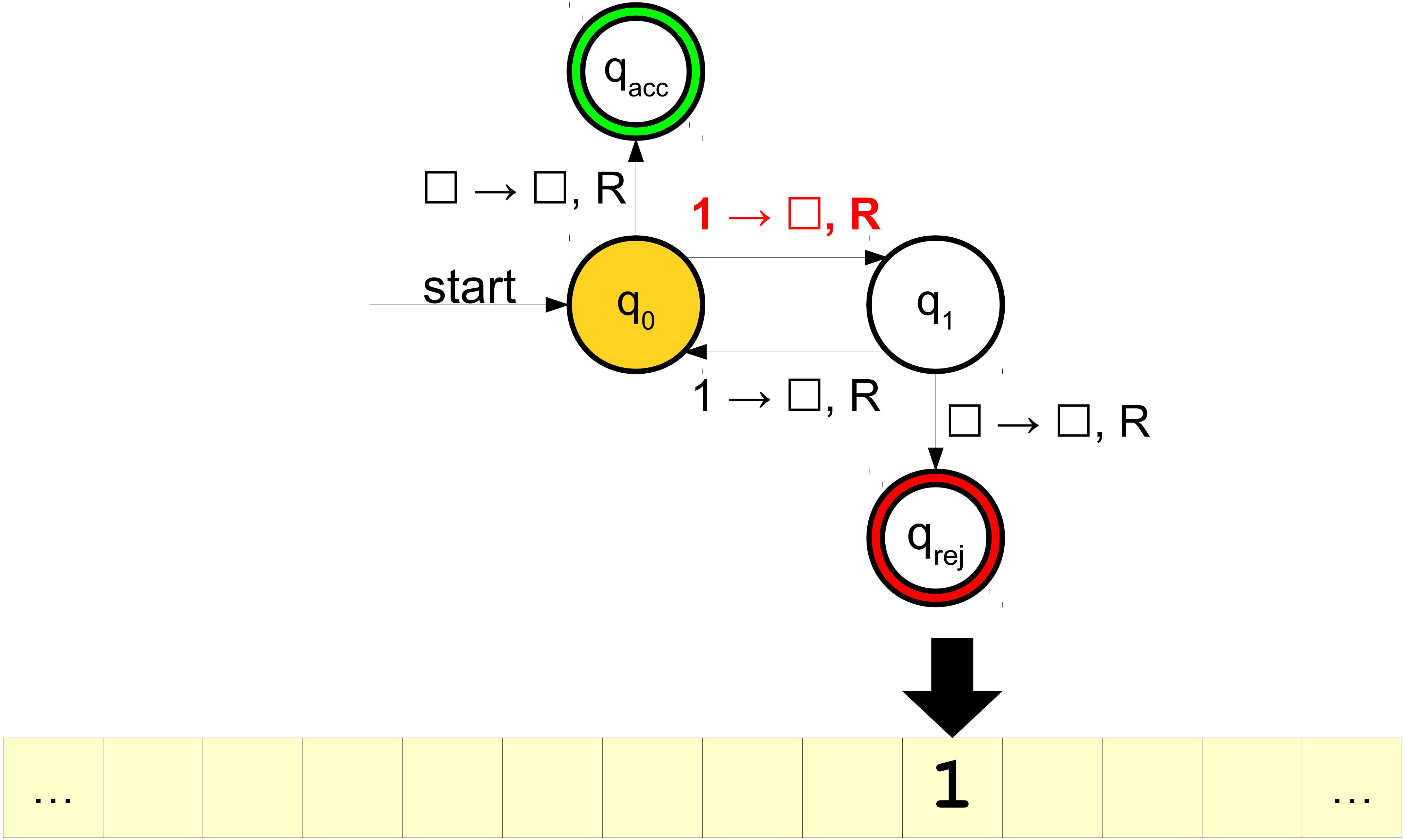
A Simple Turing Machine



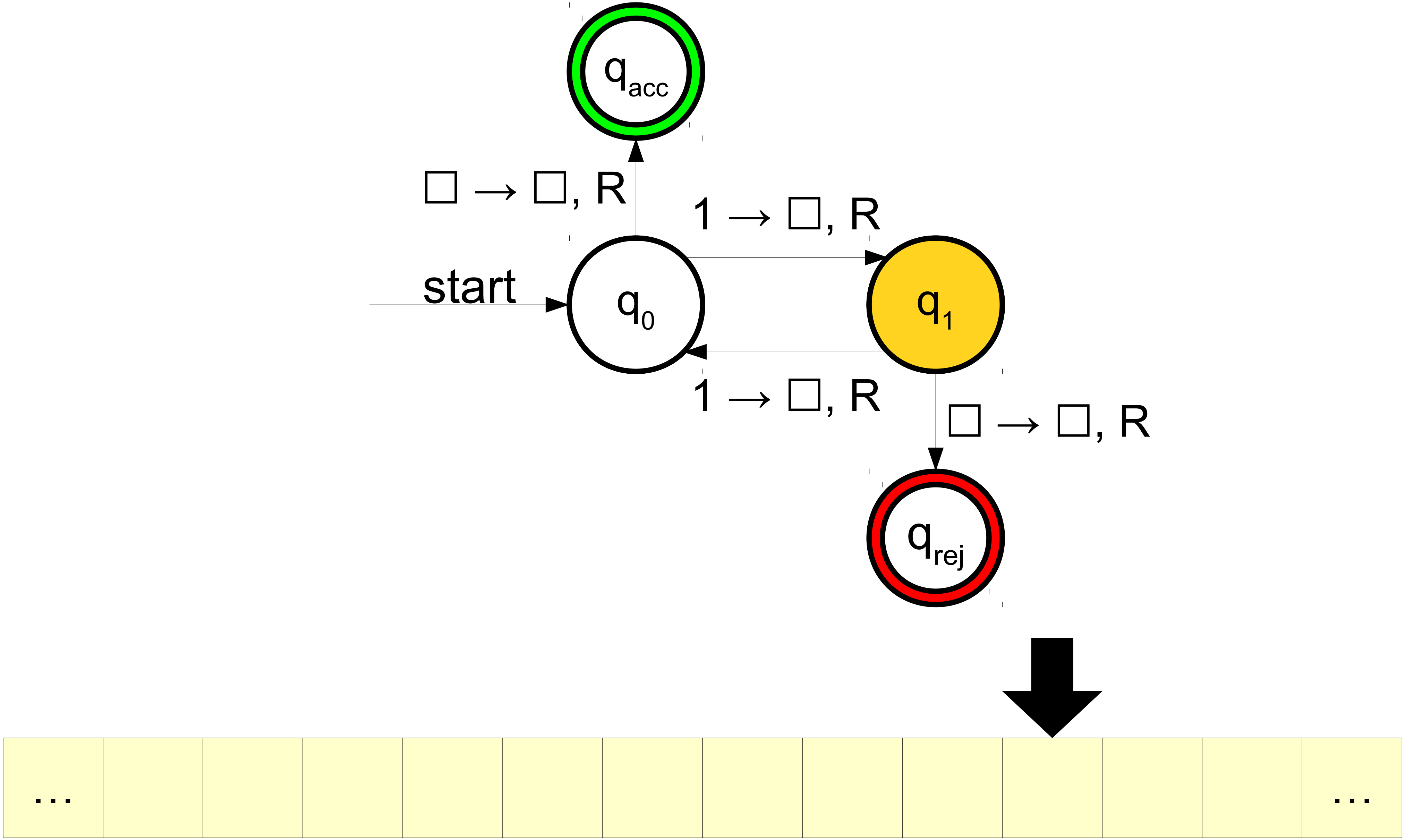
A Simple Turing Machine



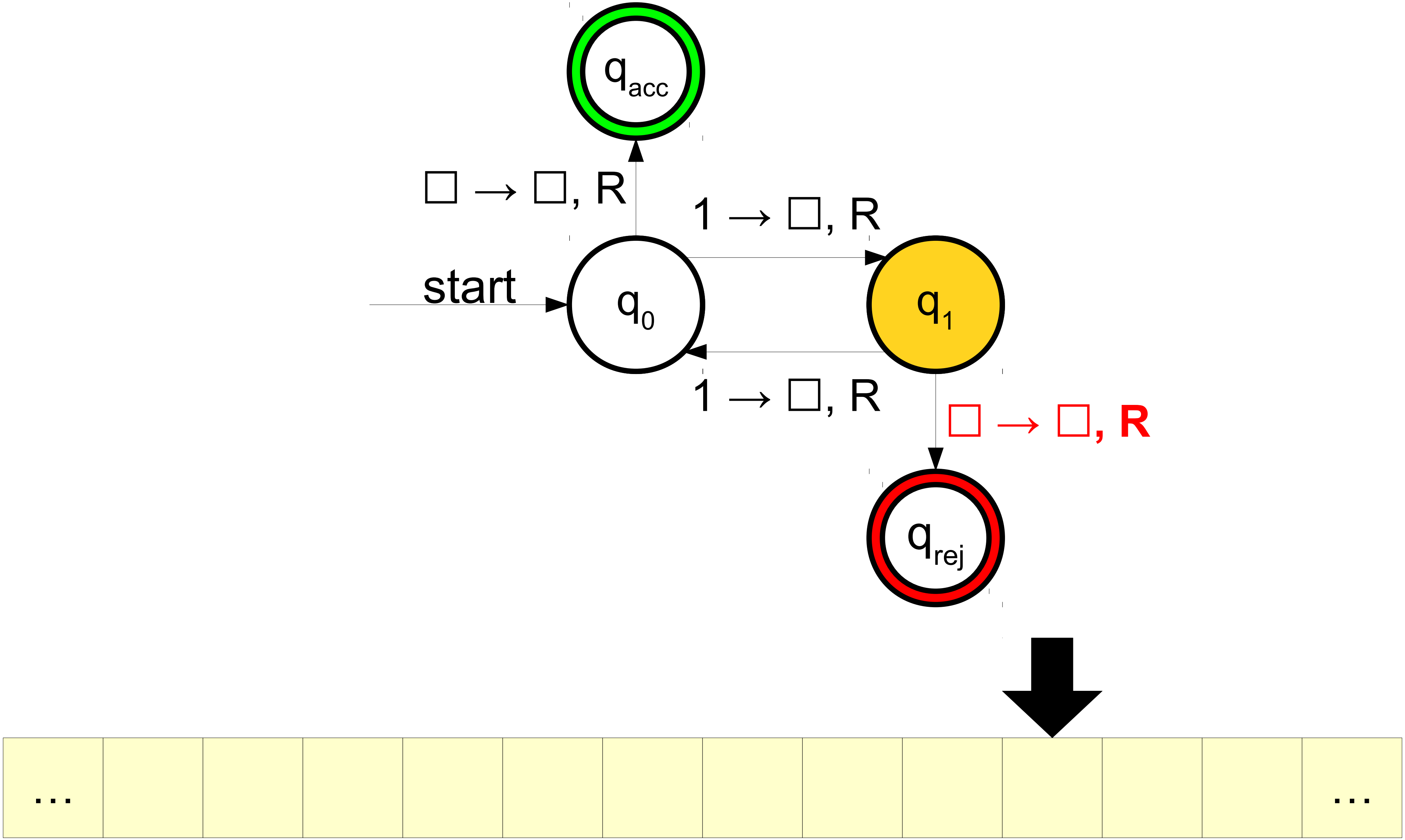
A Simple Turing Machine



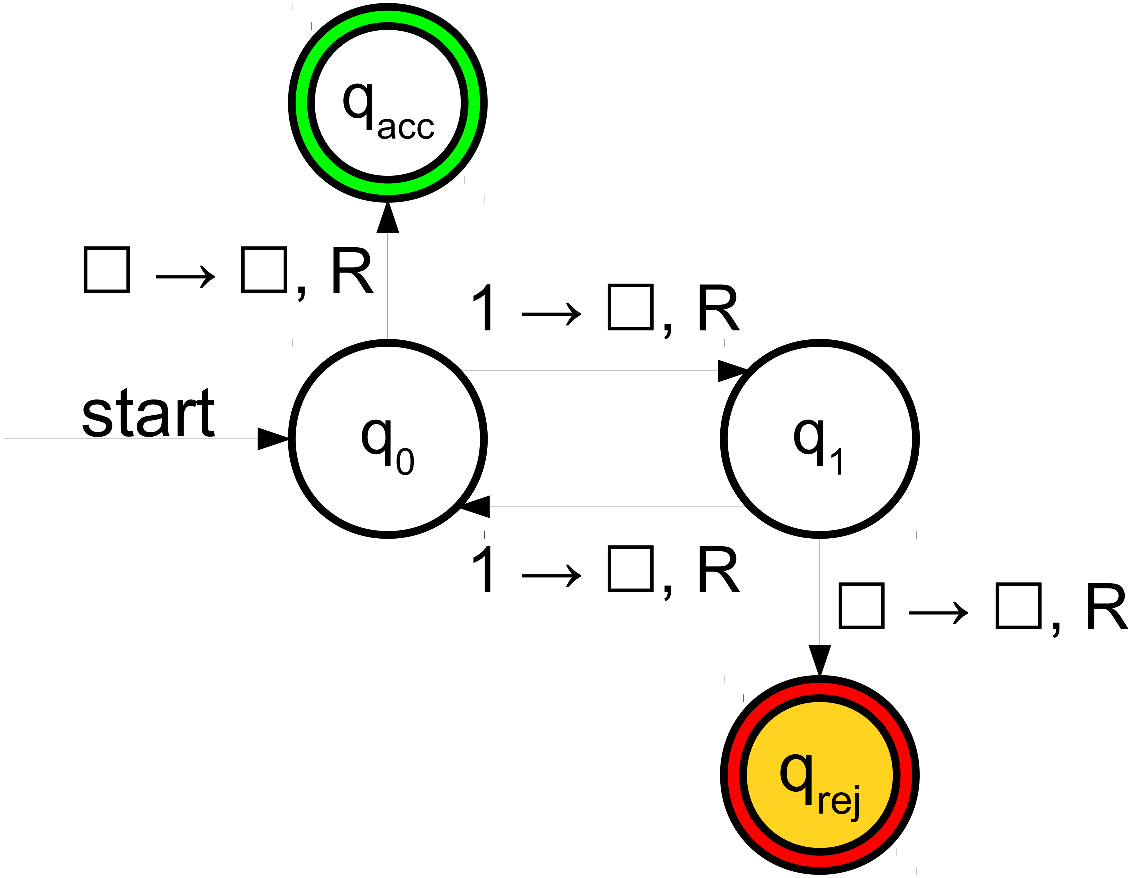
A Simple Turing Machine

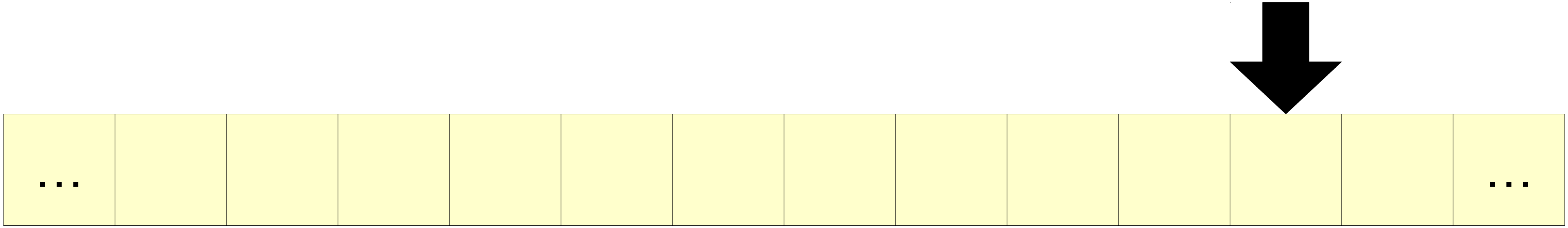


A Simple Turing Machine

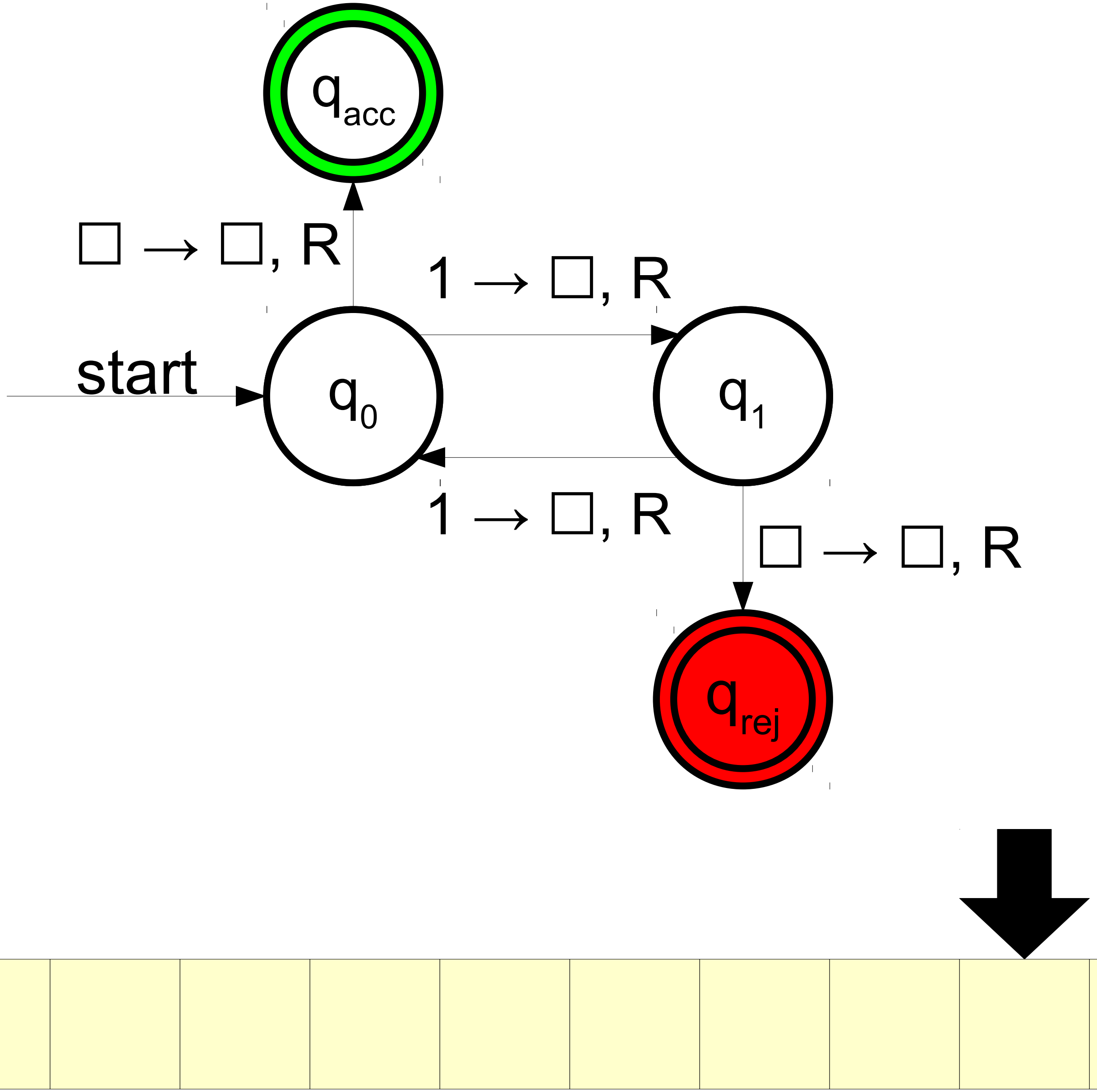


A Simple Turing Machine

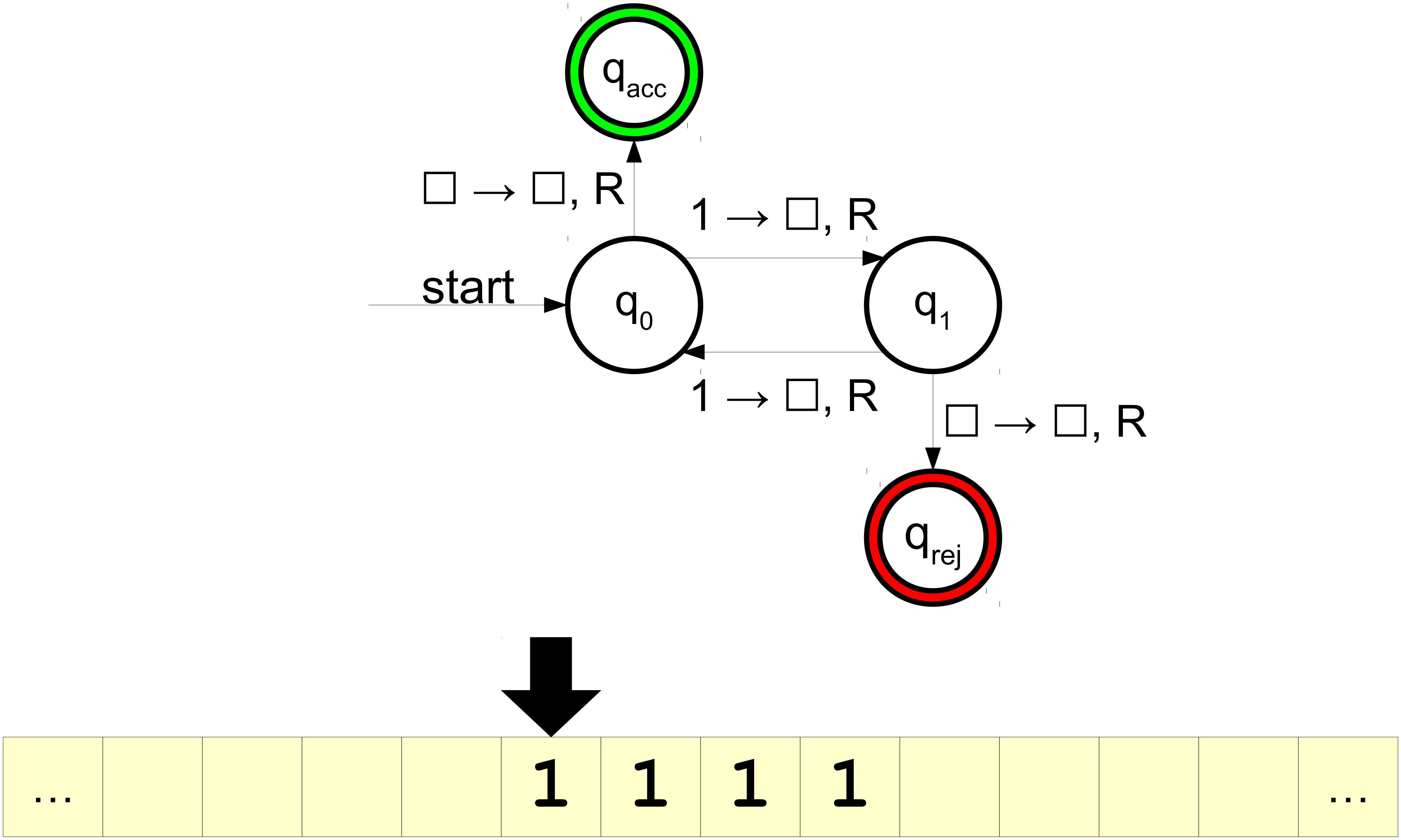




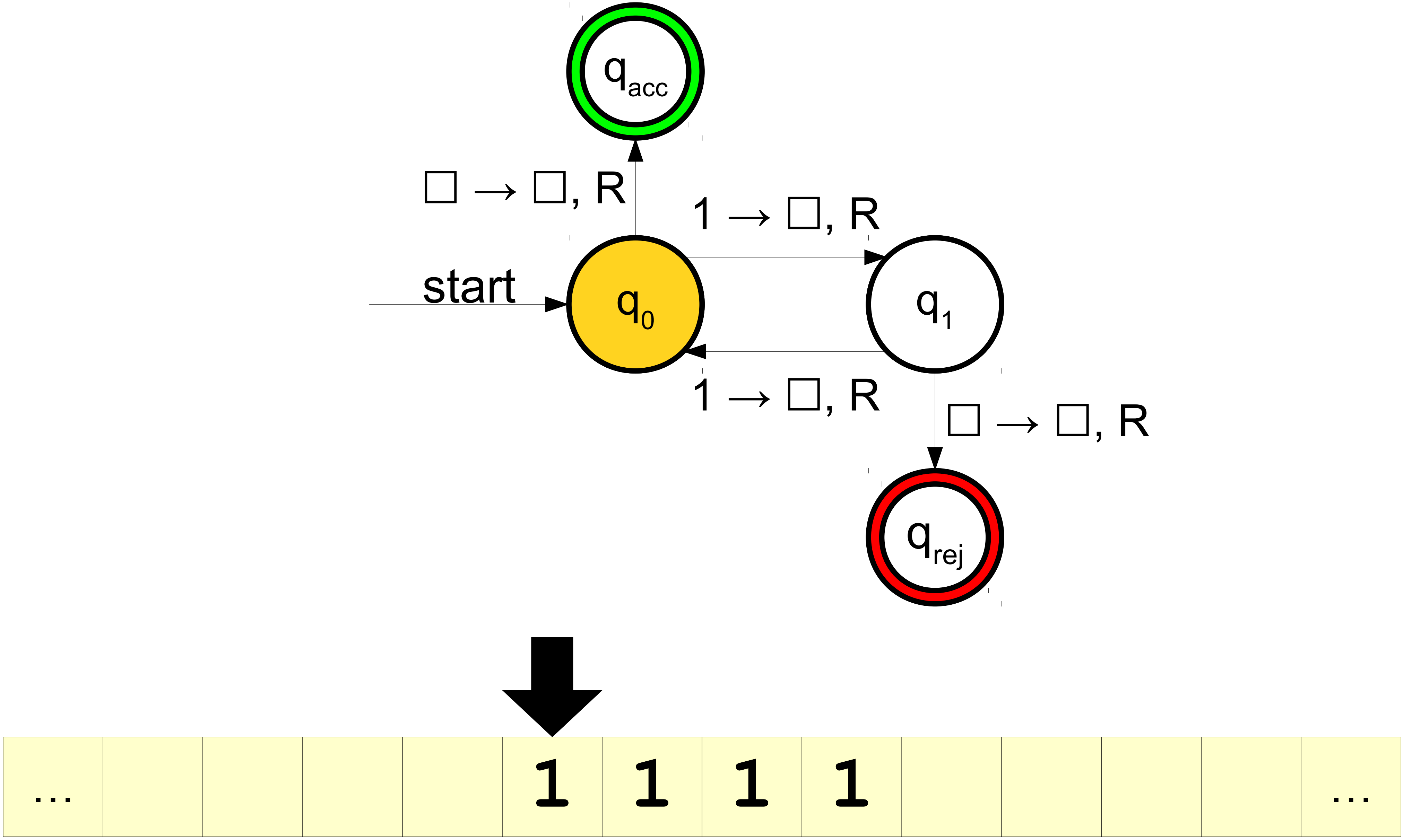
A Simple Turing Machine



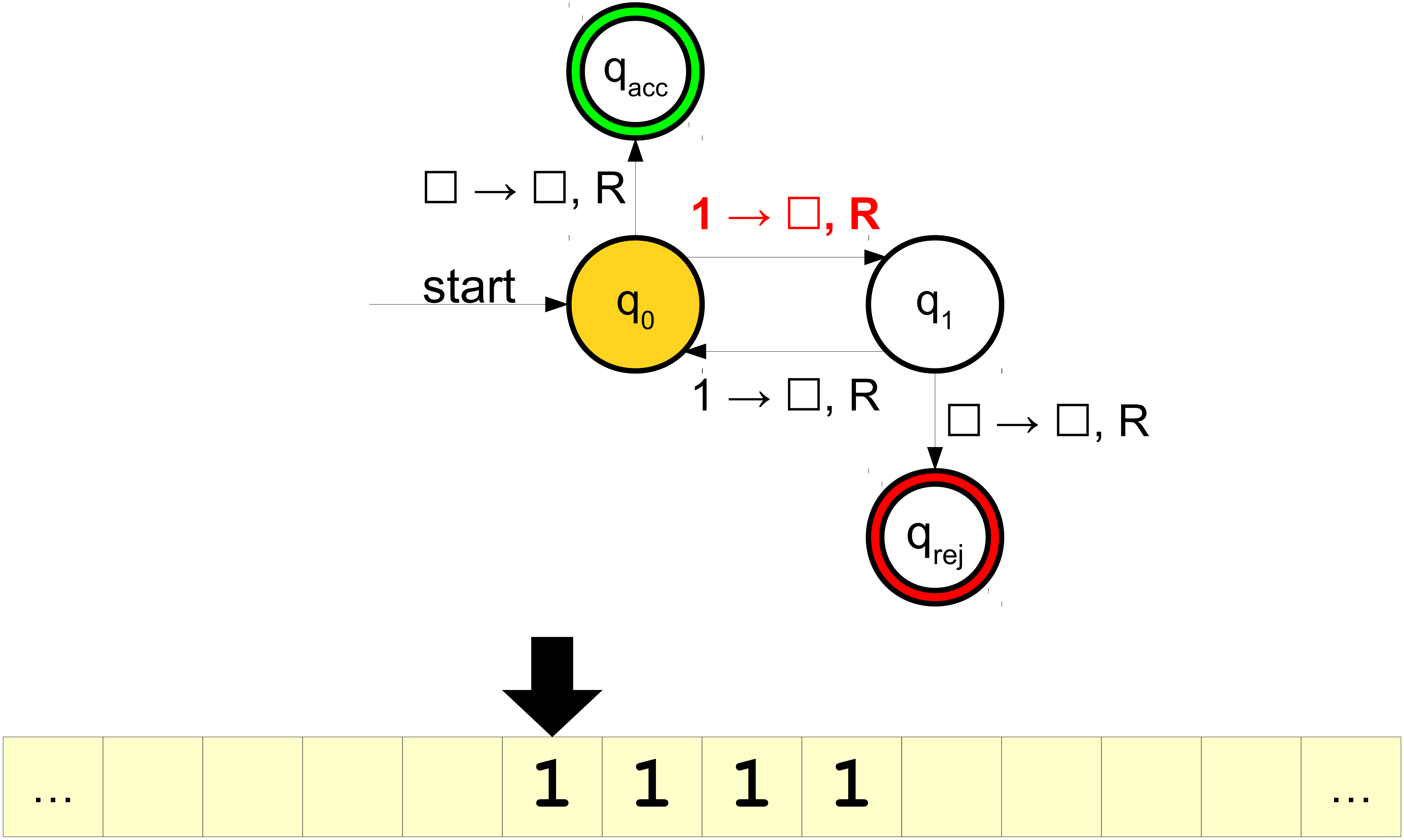
A Simple Turing Machine



A Simple Turing Machine

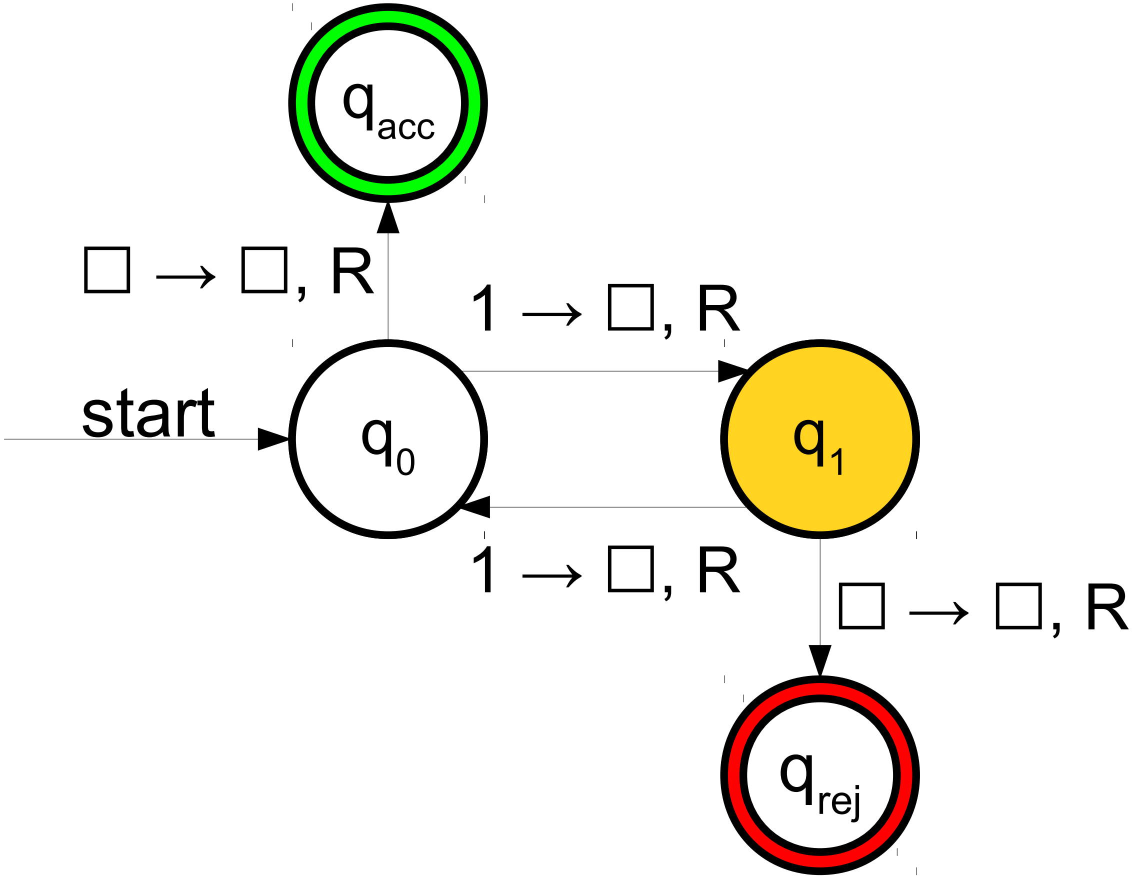


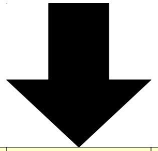
A Simple Turing Machine



…					1	1	1	1					…

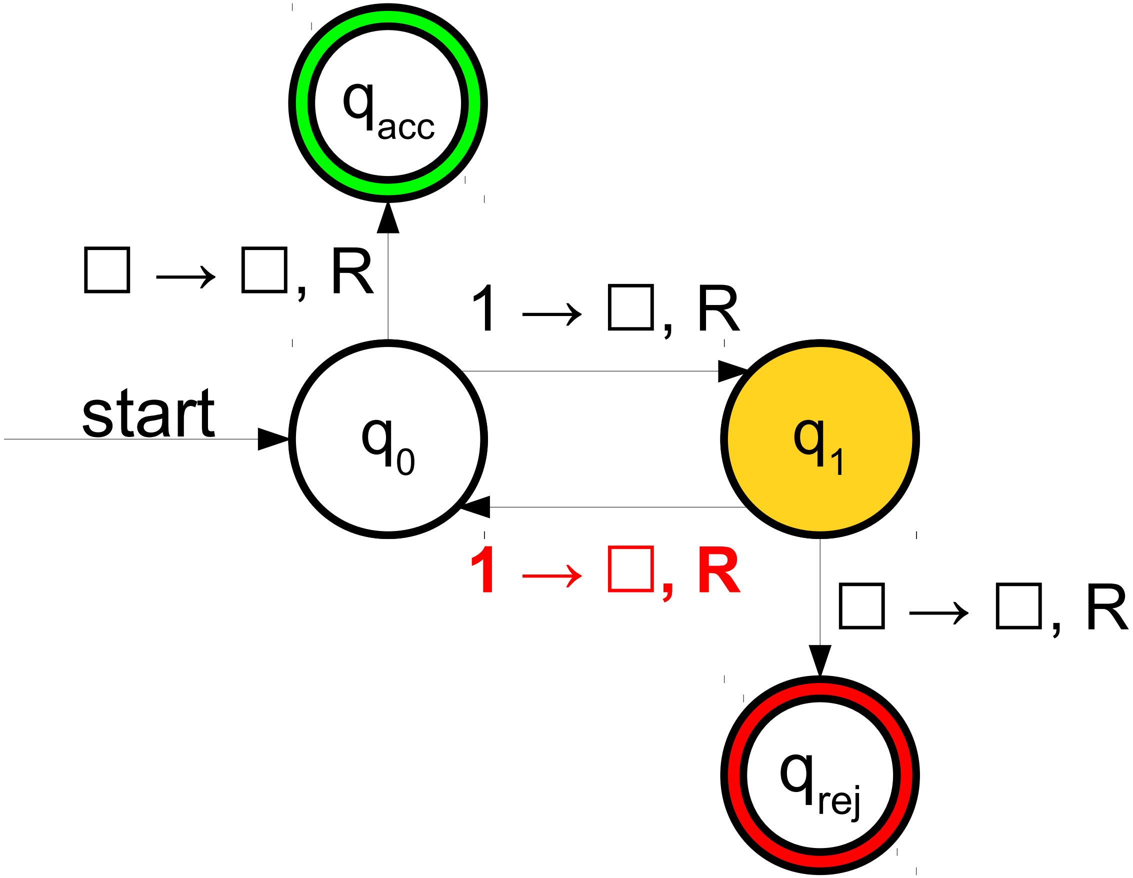
A Simple Turing Machine

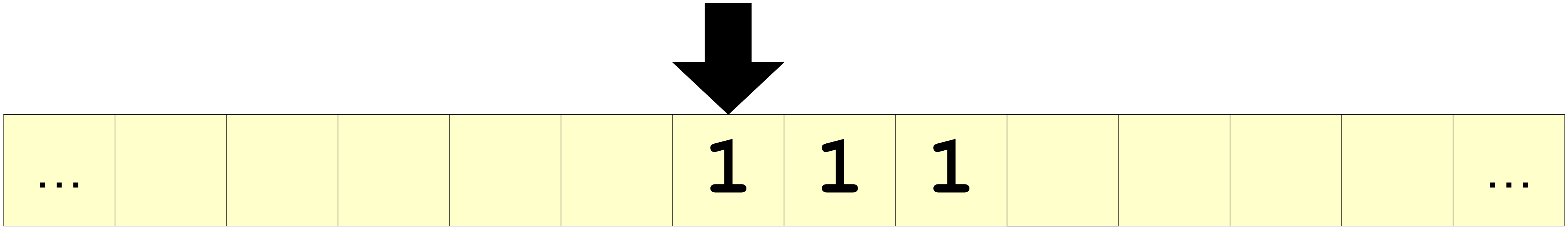




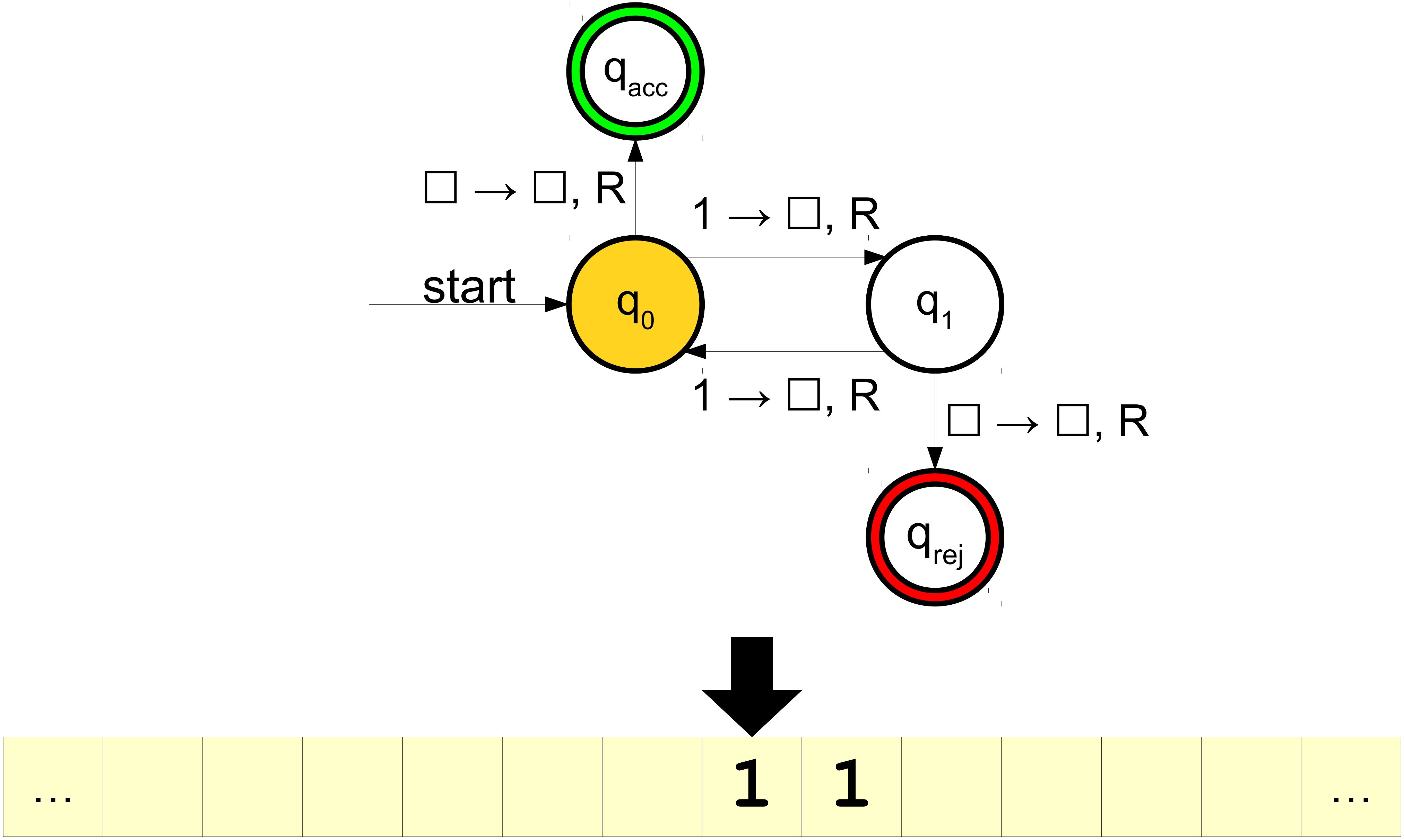
…						1	1	1					…

A Simple Turing Machine

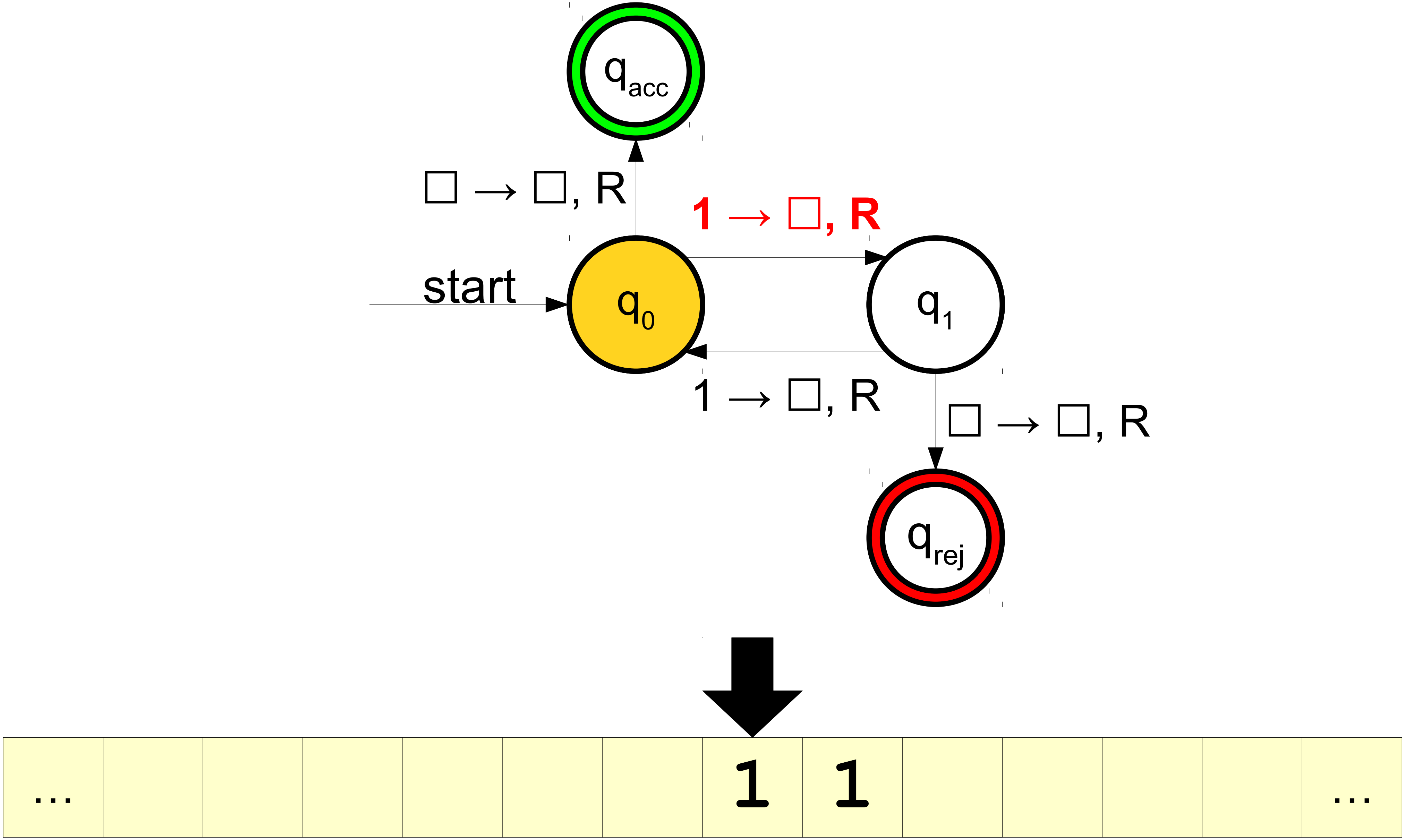




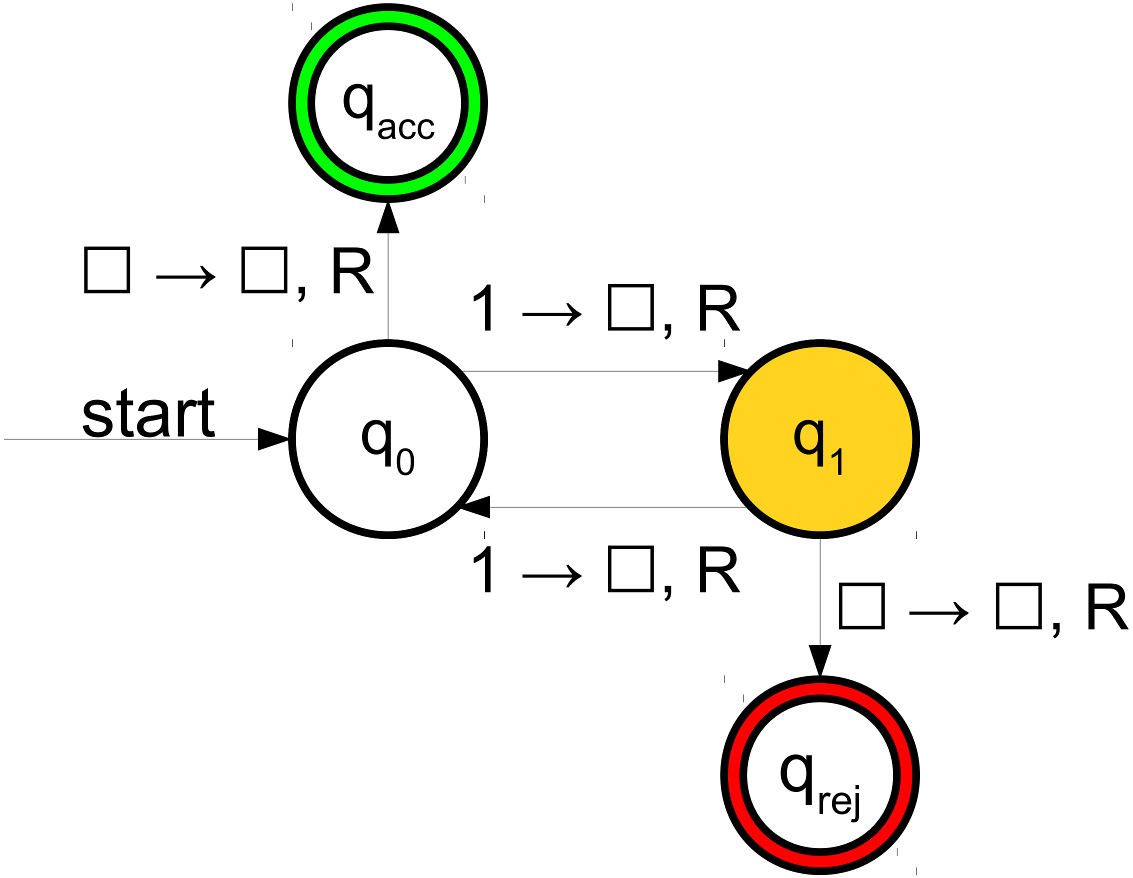
A Simple Turing Machine

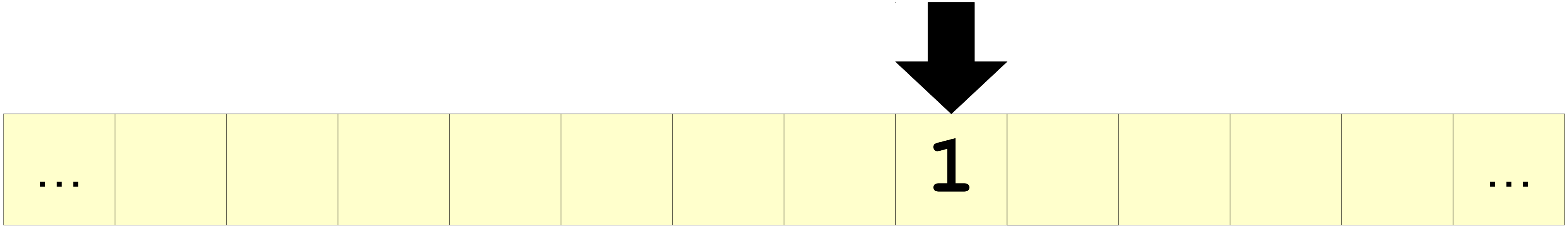


A Simple Turing Machine

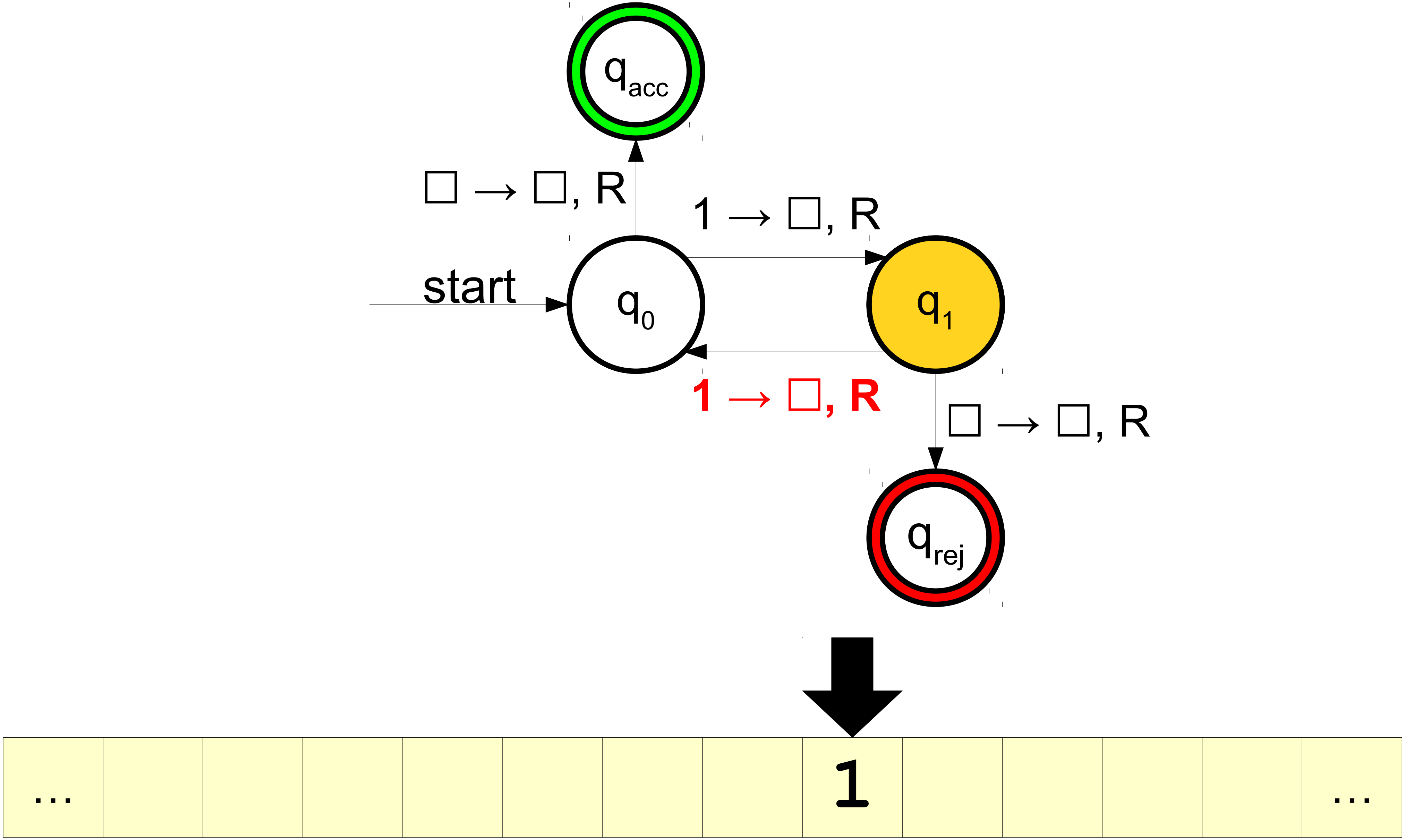


A Simple Turing Machine

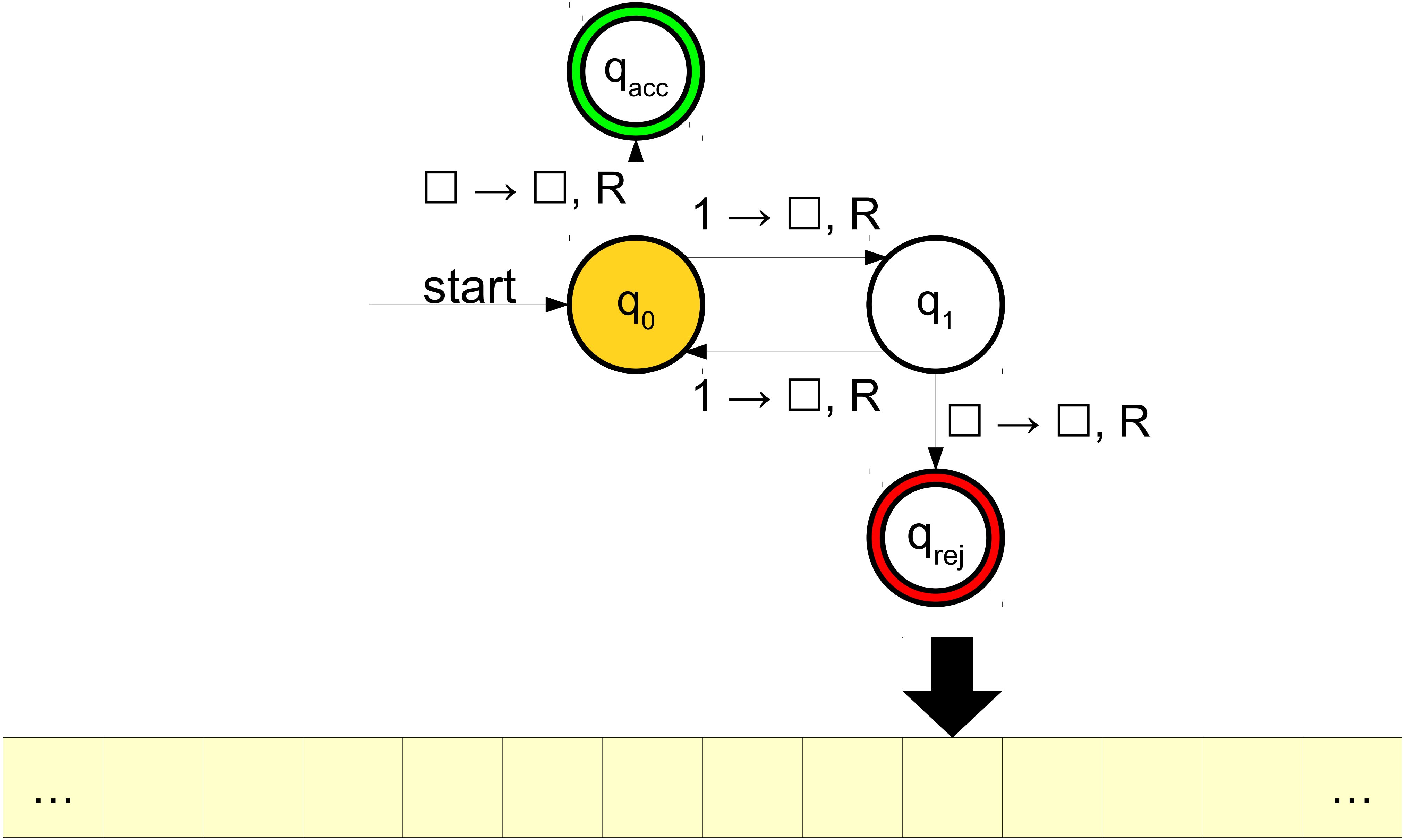




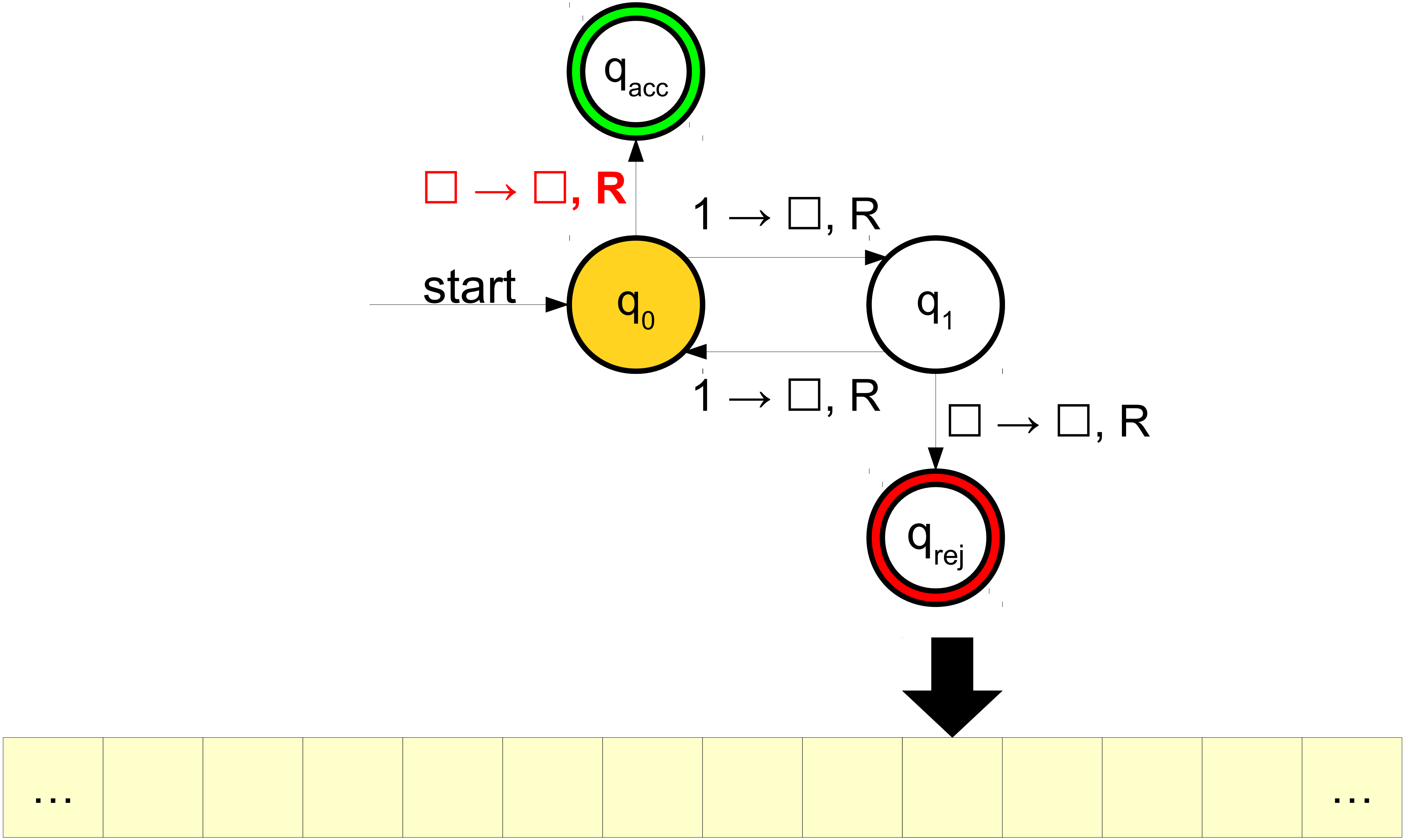
A Simple Turing Machine



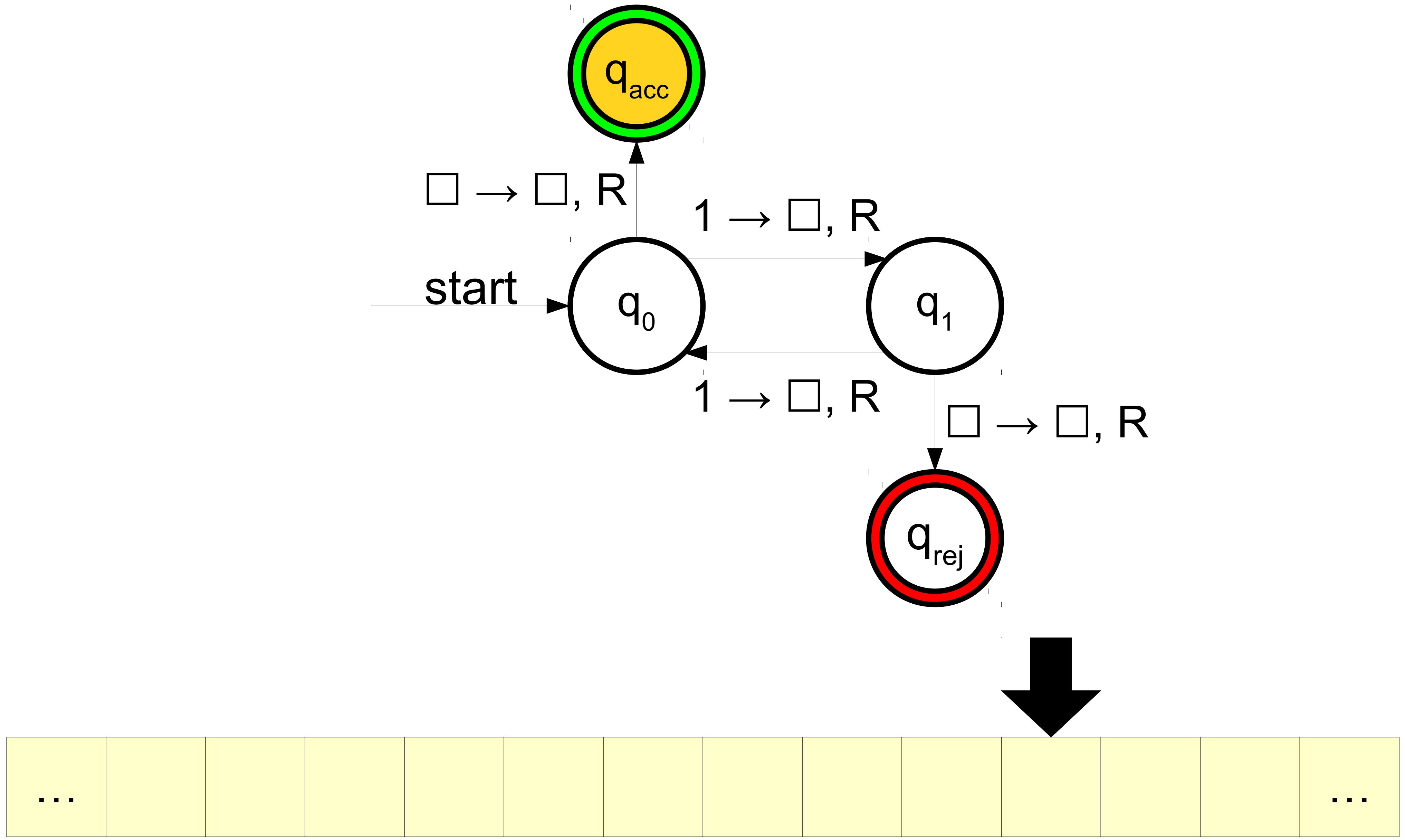
A Simple Turing Machine



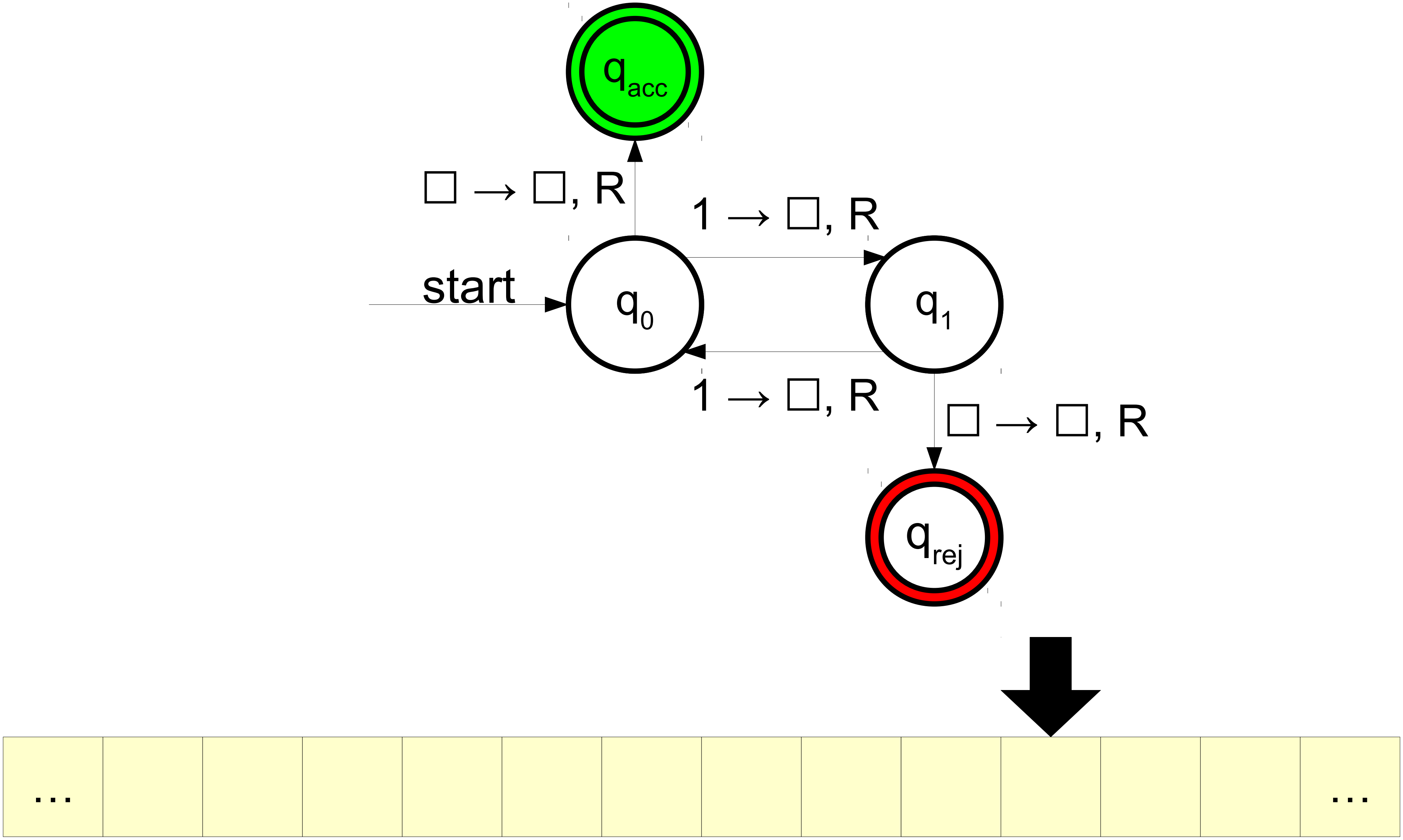
A Simple Turing Machine



A Simple Turing Machine



A Simple Turing Machine



Accepting and Rejecting States

- Unlike DFAs, Turing machines do not stop processing the input when they finish reading it.
- Turing machines decide when (and if!) they will accept or reject their input.
- Turing machines can enter infinite loops and never accept or reject; more on that later…

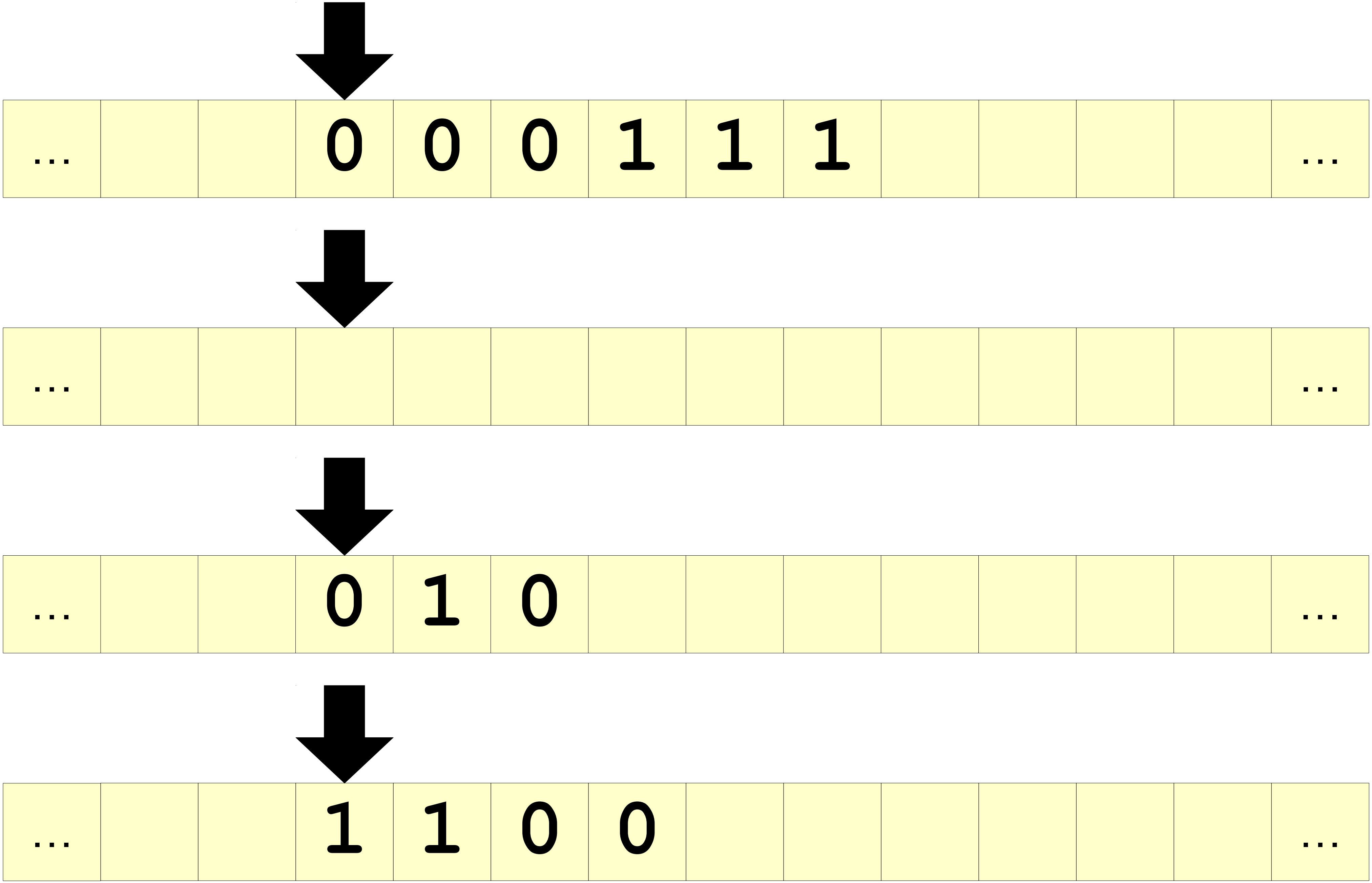
Designing Turing Machines

- Despite their simplicity, Turing machines are very powerful computing devices.
- Today's lecture explores how to design Turing machines for various languages.

Designing Turing Machines

- Let $\Sigma = \{\texttt{0}, \texttt{1}\}$ and consider the language $L = \{\texttt{0}^n\texttt{1}^n \mid n \in \mathbb{N}\}$.
- We know that L is context-free.
- How might we build a Turing machine for it?

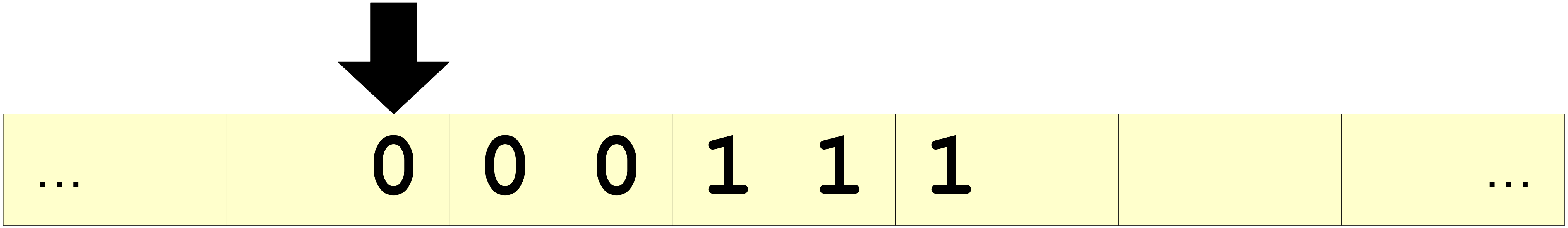
$$L = \{ \mathtt{0}^n\mathtt{1}^n \mid n \in \mathbb{N} \}$$



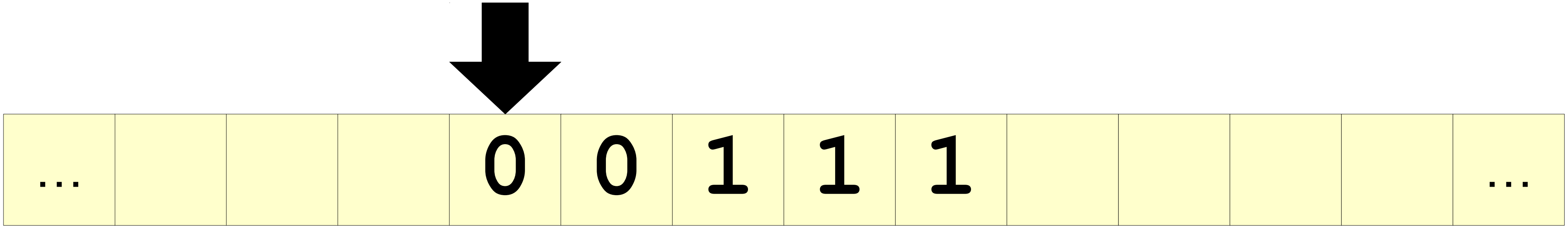
A Recursive Approach

- The string ε is in L.
- The string `0`w`1` is in L iff w is in L.
- Any string starting with `1` is not in L.
- Any string ending with `0` is not in L.

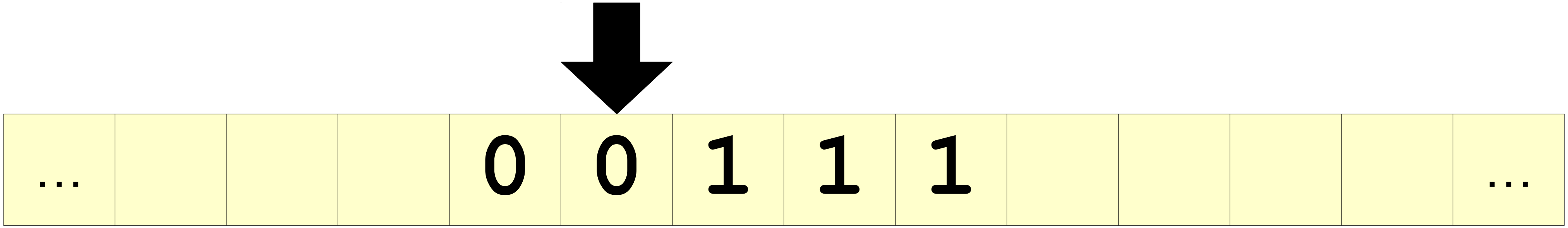
A Sketch of the TM



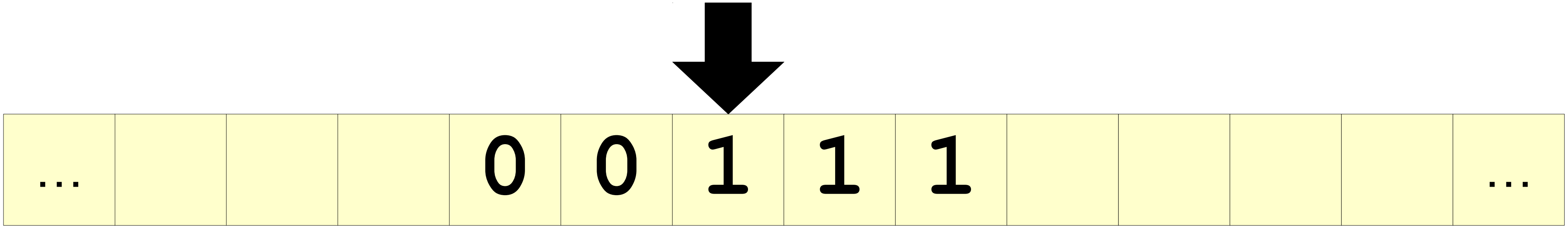
A Sketch of the TM



A Sketch of the TM

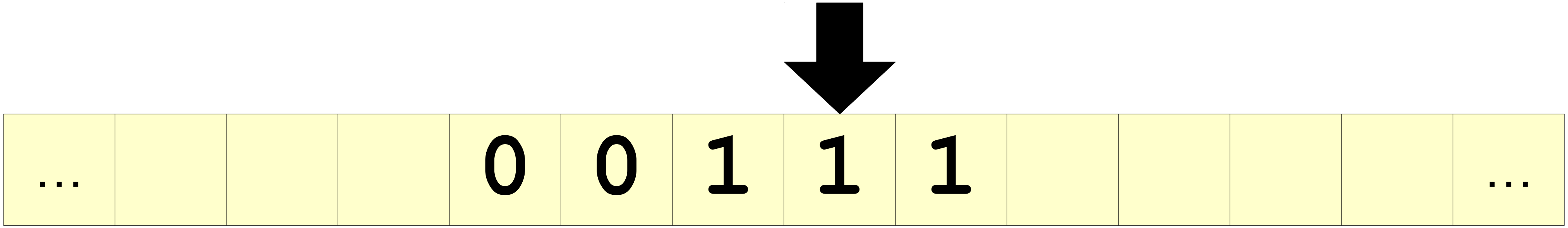


A Sketch of the TM



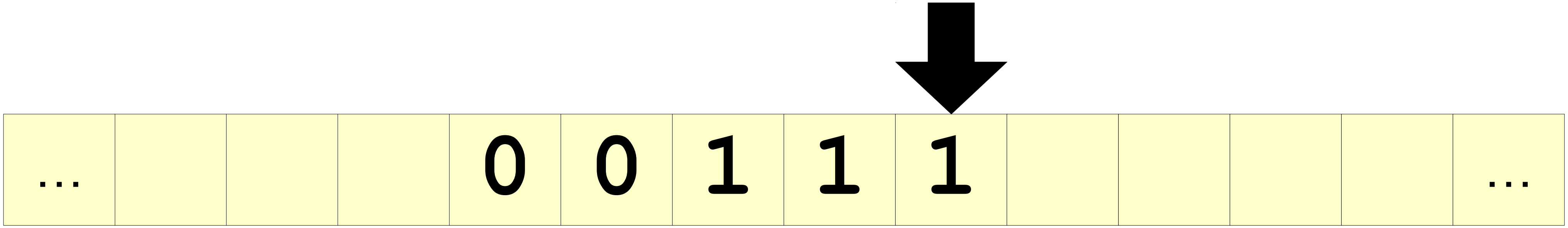
…				0	0	1	1	1					…

A Sketch of the TM

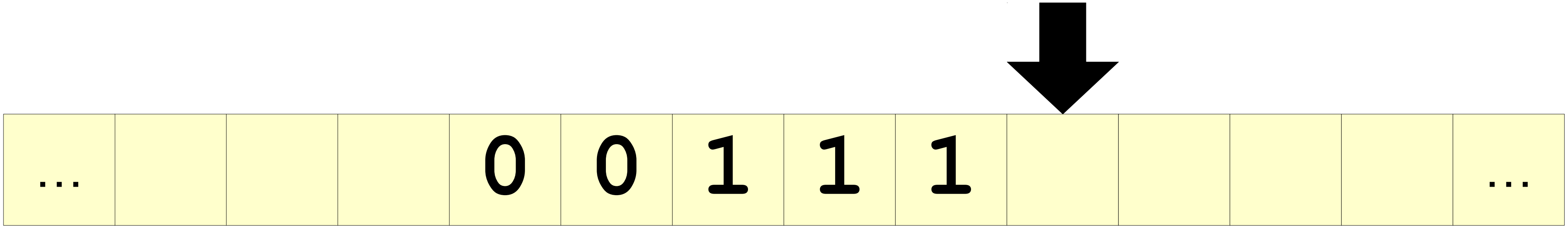


… 0 0 1 1 1 …

A Sketch of the TM

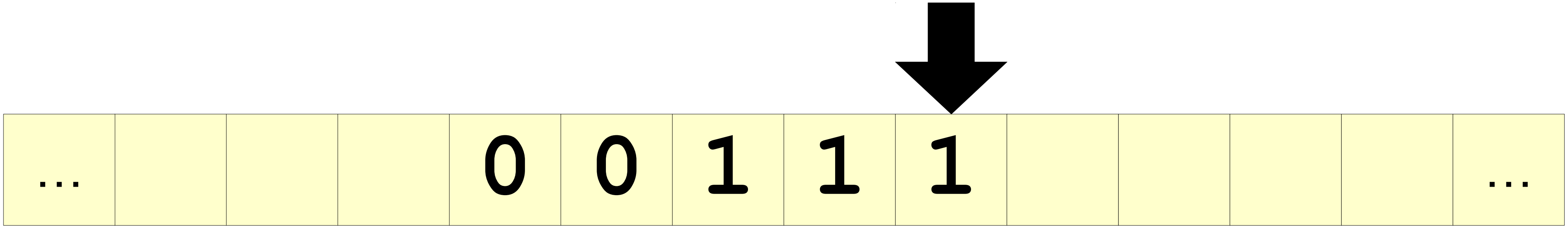


A Sketch of the TM

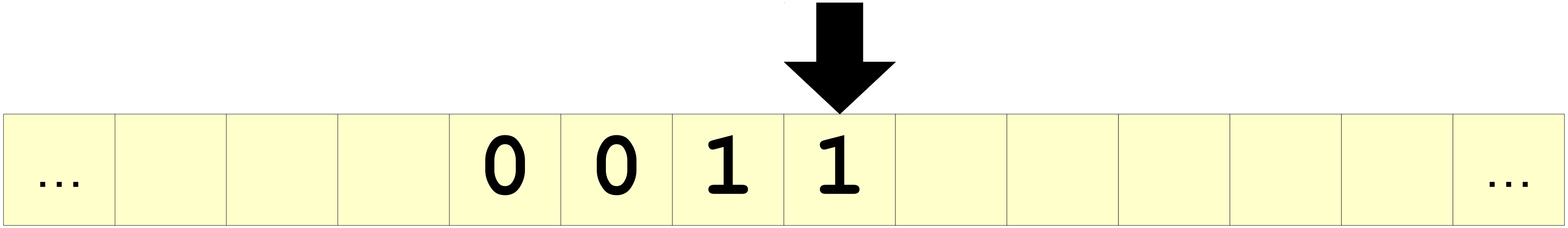


… 0 0 1 1 1 …

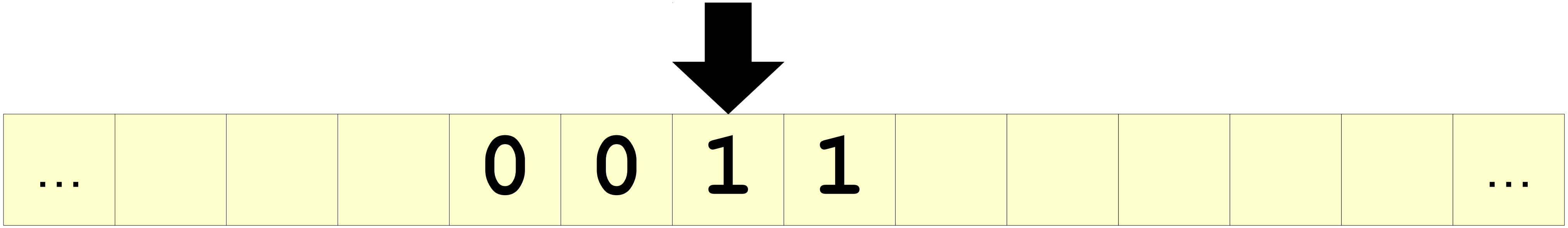
A Sketch of the TM



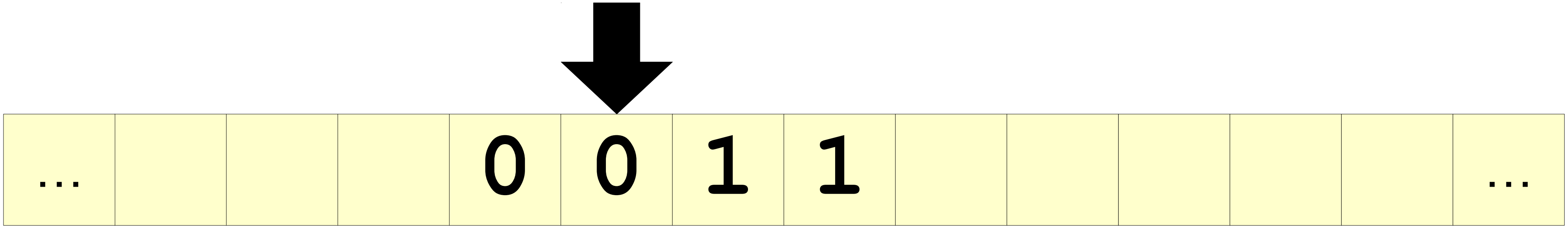
A Sketch of the TM



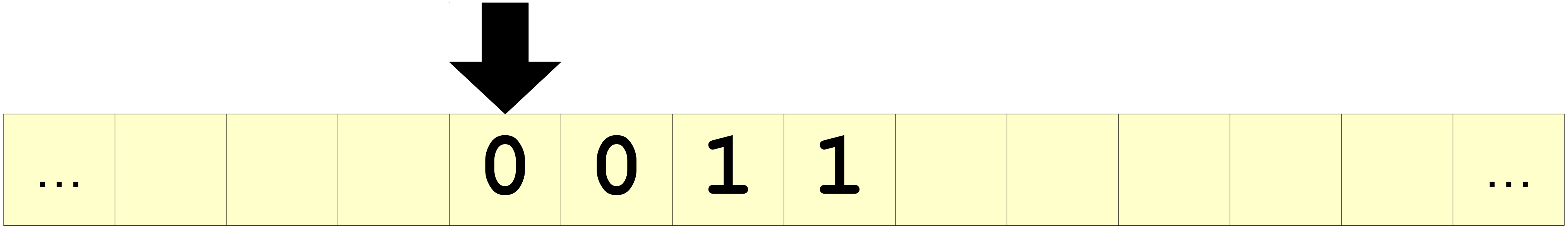
A Sketch of the TM



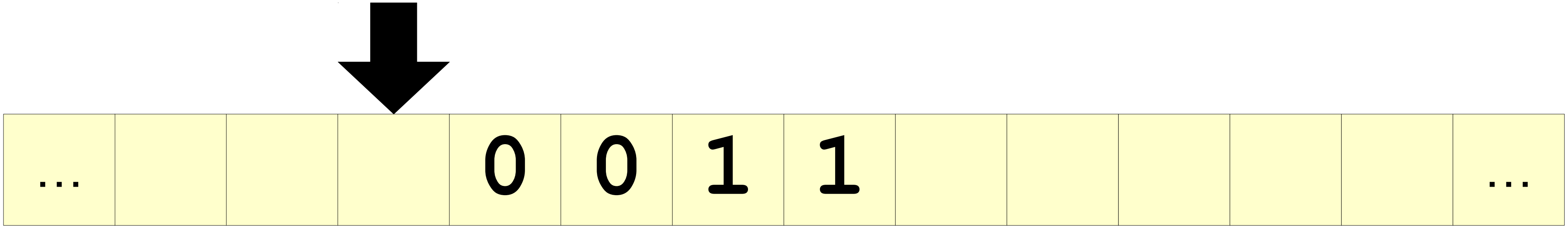
A Sketch of the TM



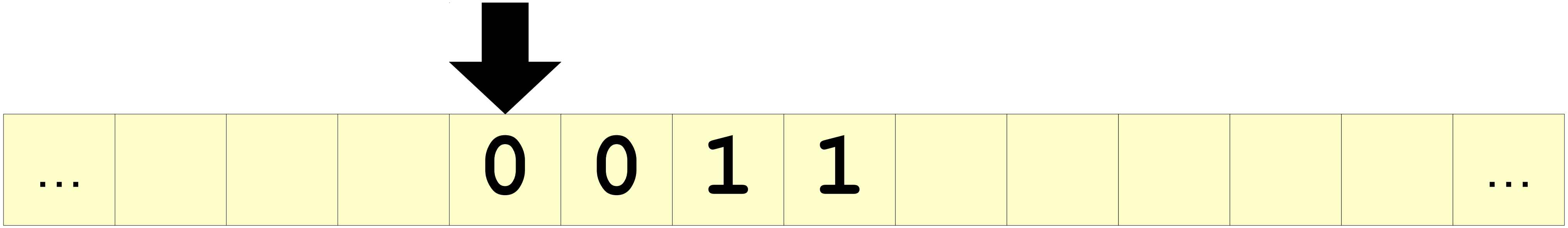
A Sketch of the TM



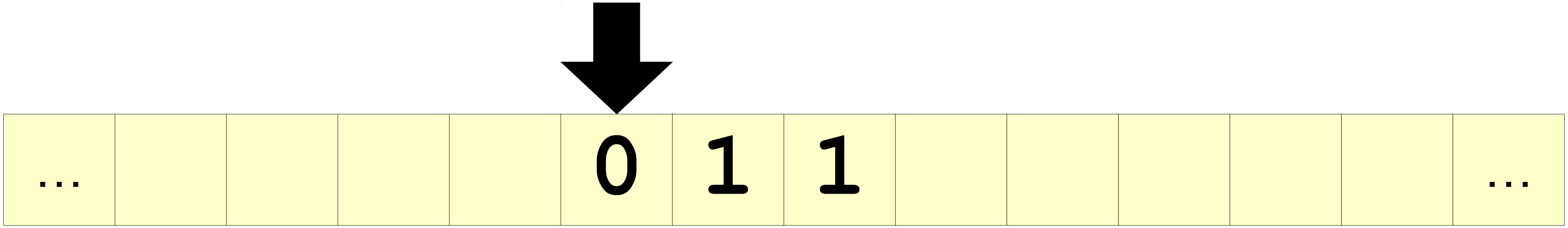
A Sketch of the TM



A Sketch of the TM

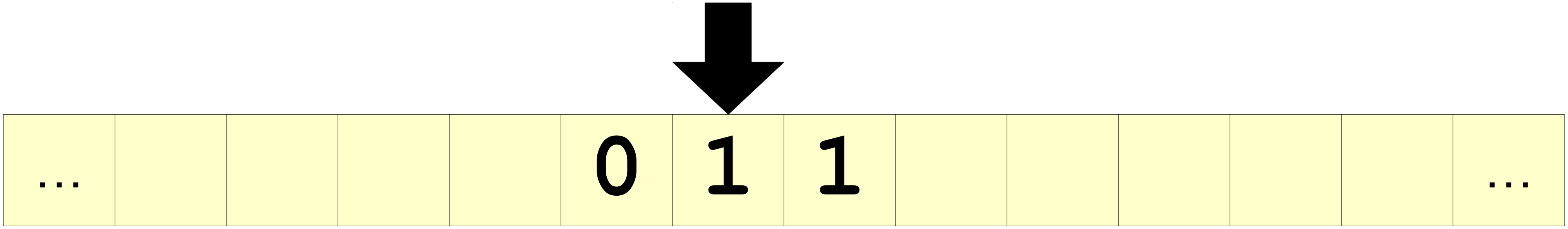


A Sketch of the TM

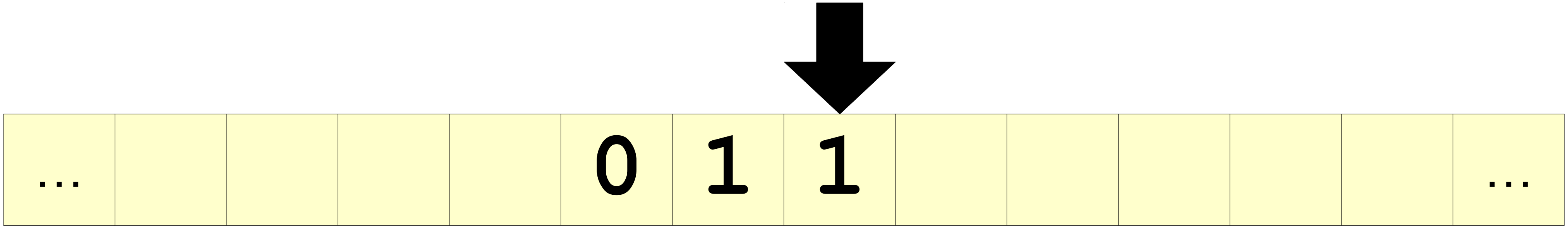


… 0 1 1 …

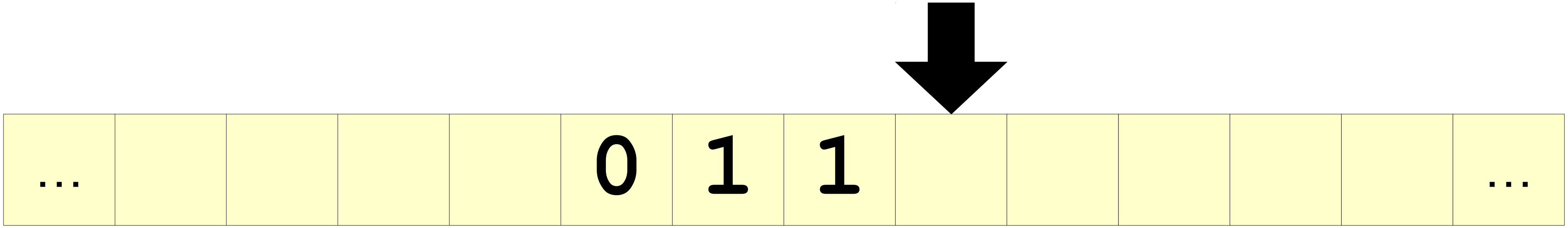
A Sketch of the TM



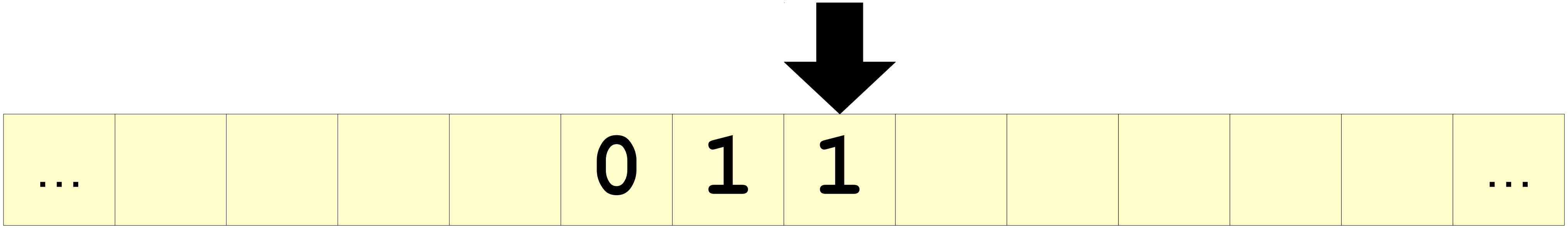
A Sketch of the TM



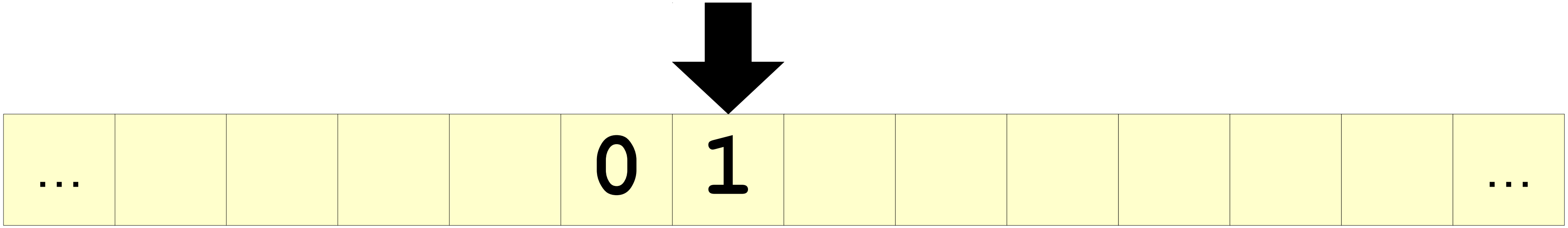
A Sketch of the TM



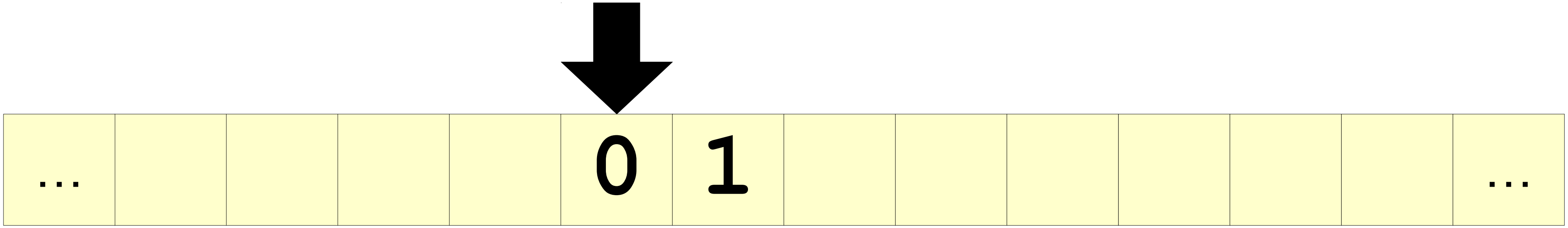
A Sketch of the TM



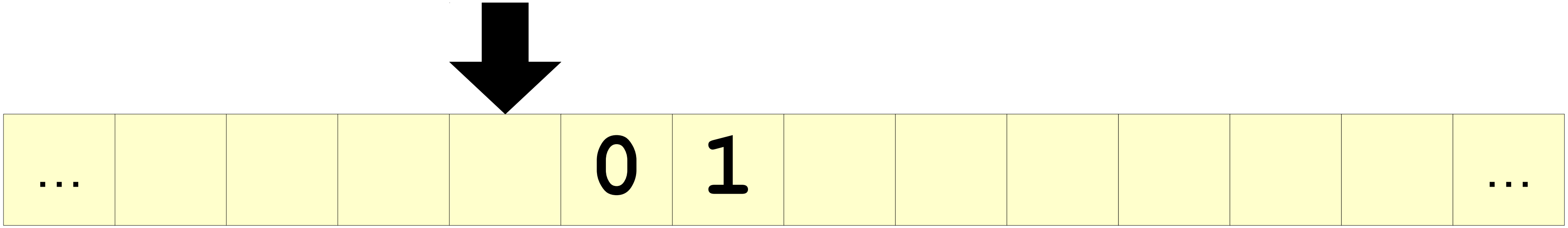
A Sketch of the TM



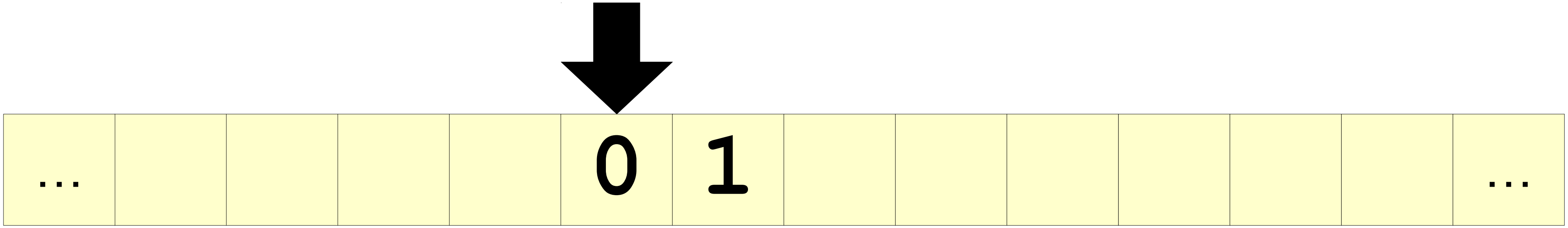
A Sketch of the TM



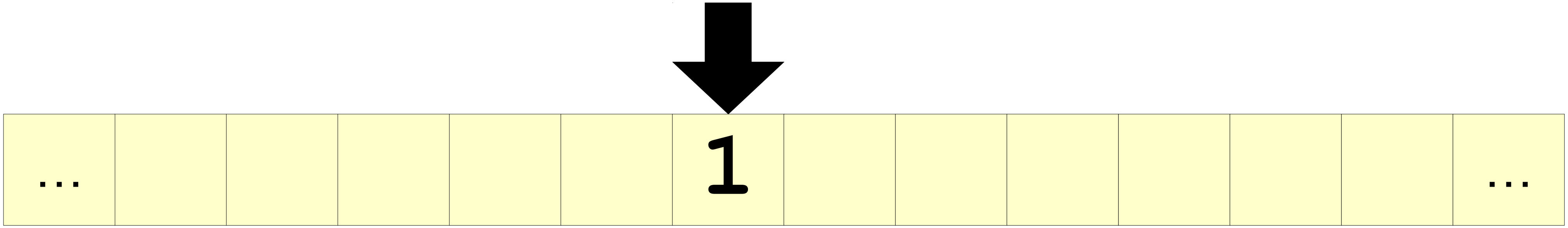
A Sketch of the TM



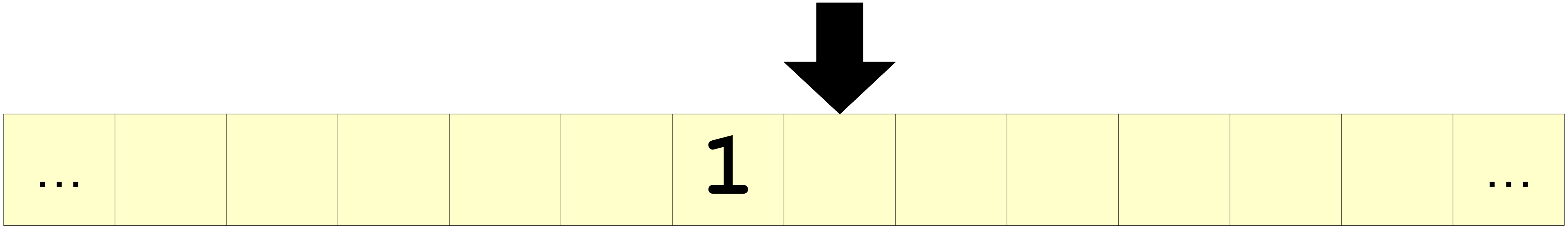
A Sketch of the TM



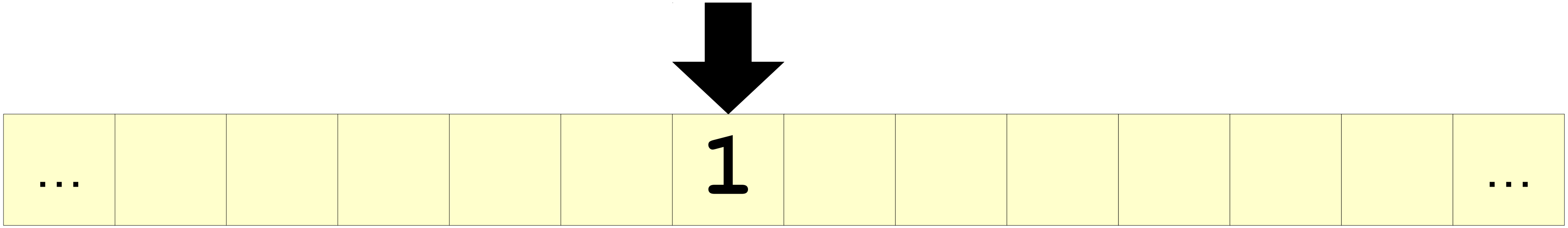
A Sketch of the TM



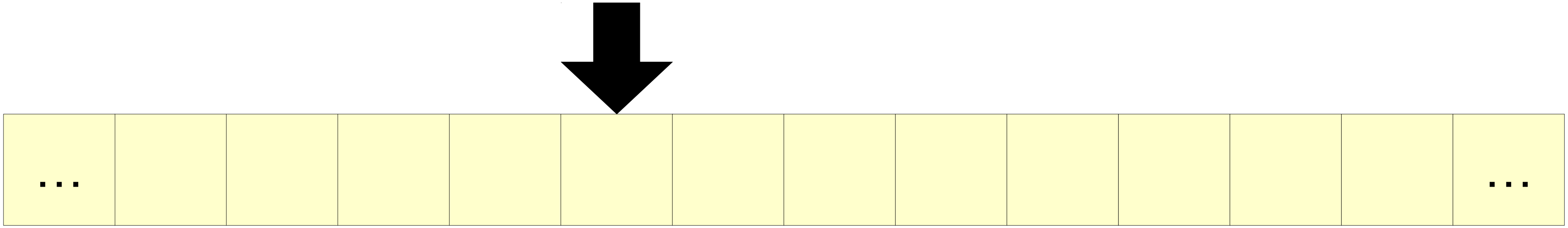
A Sketch of the TM



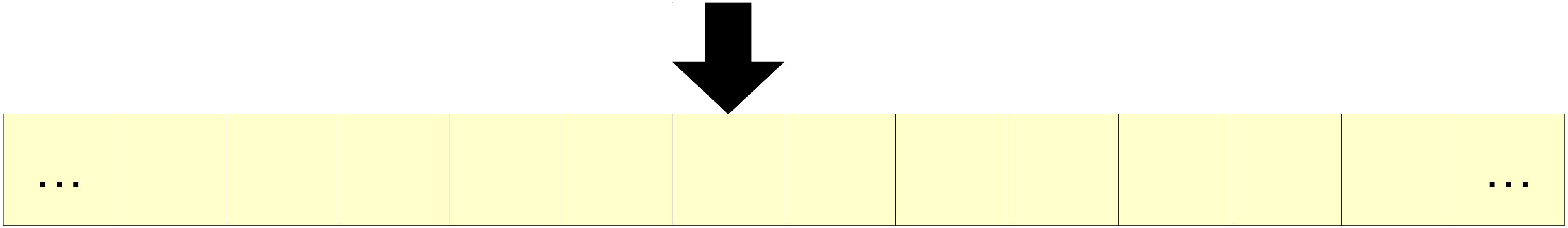
A Sketch of the TM

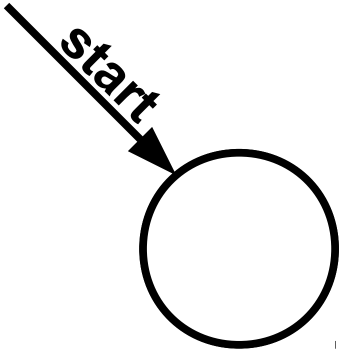


A Sketch of the TM

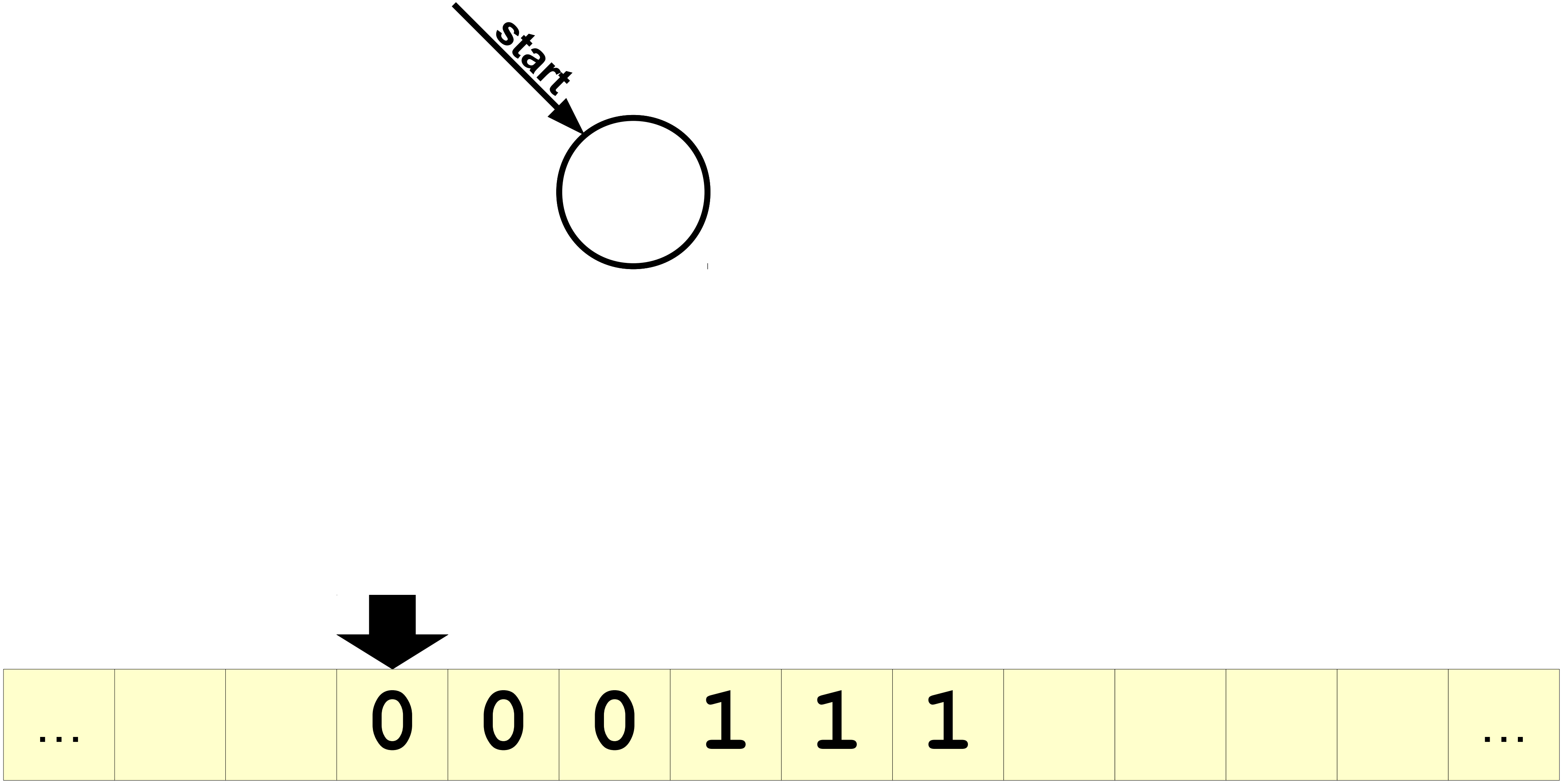


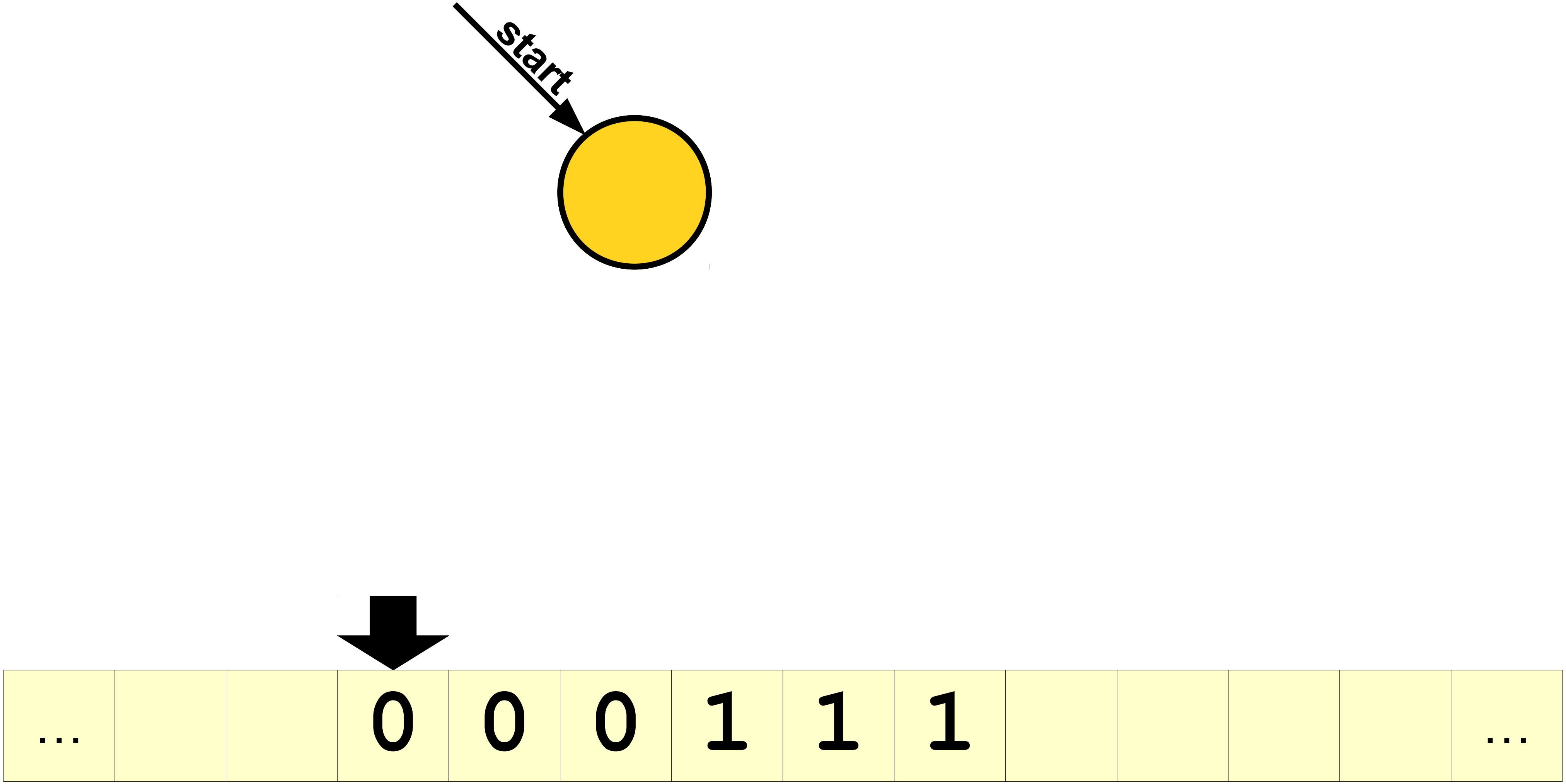
A Sketch of the TM

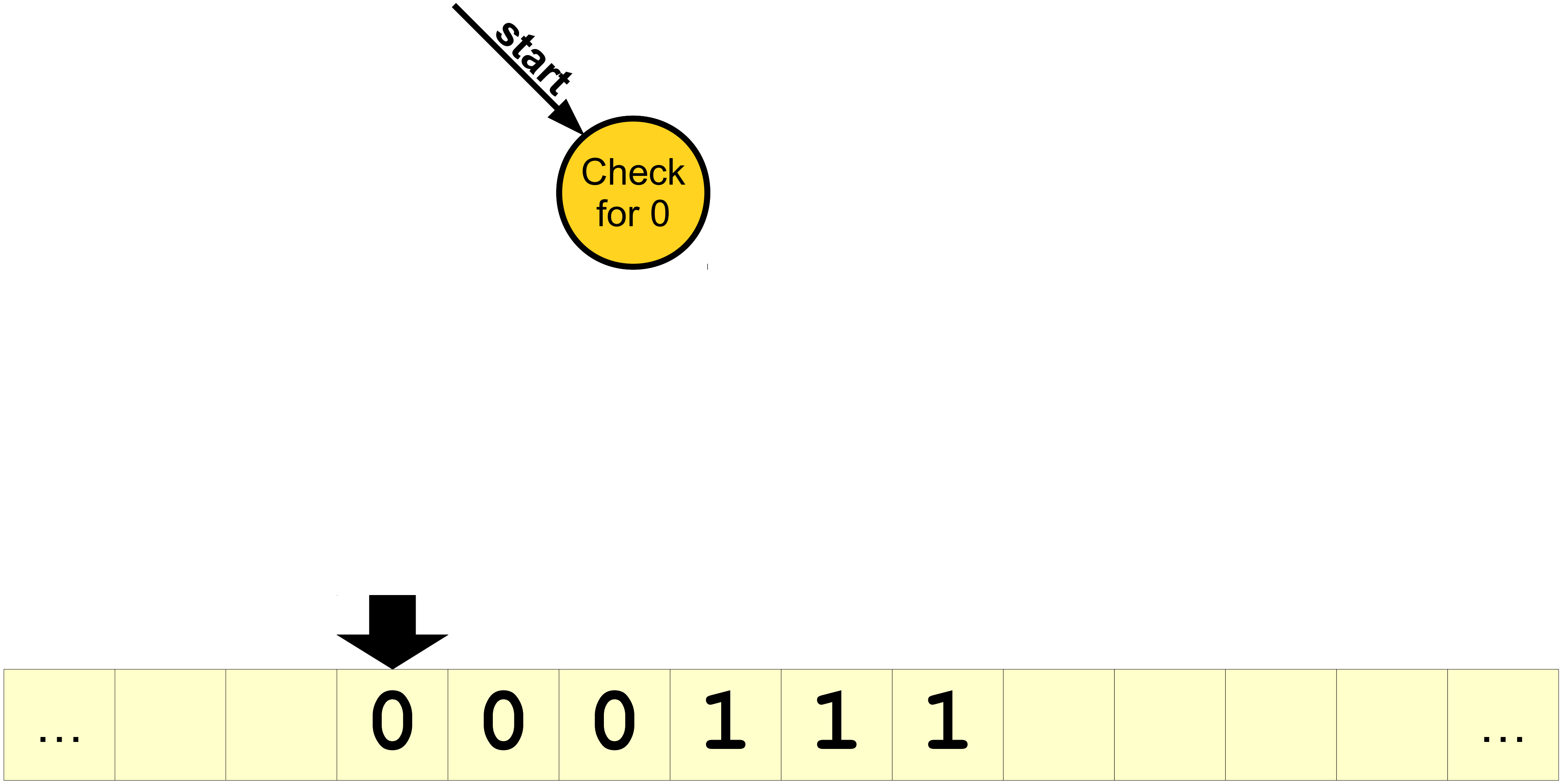


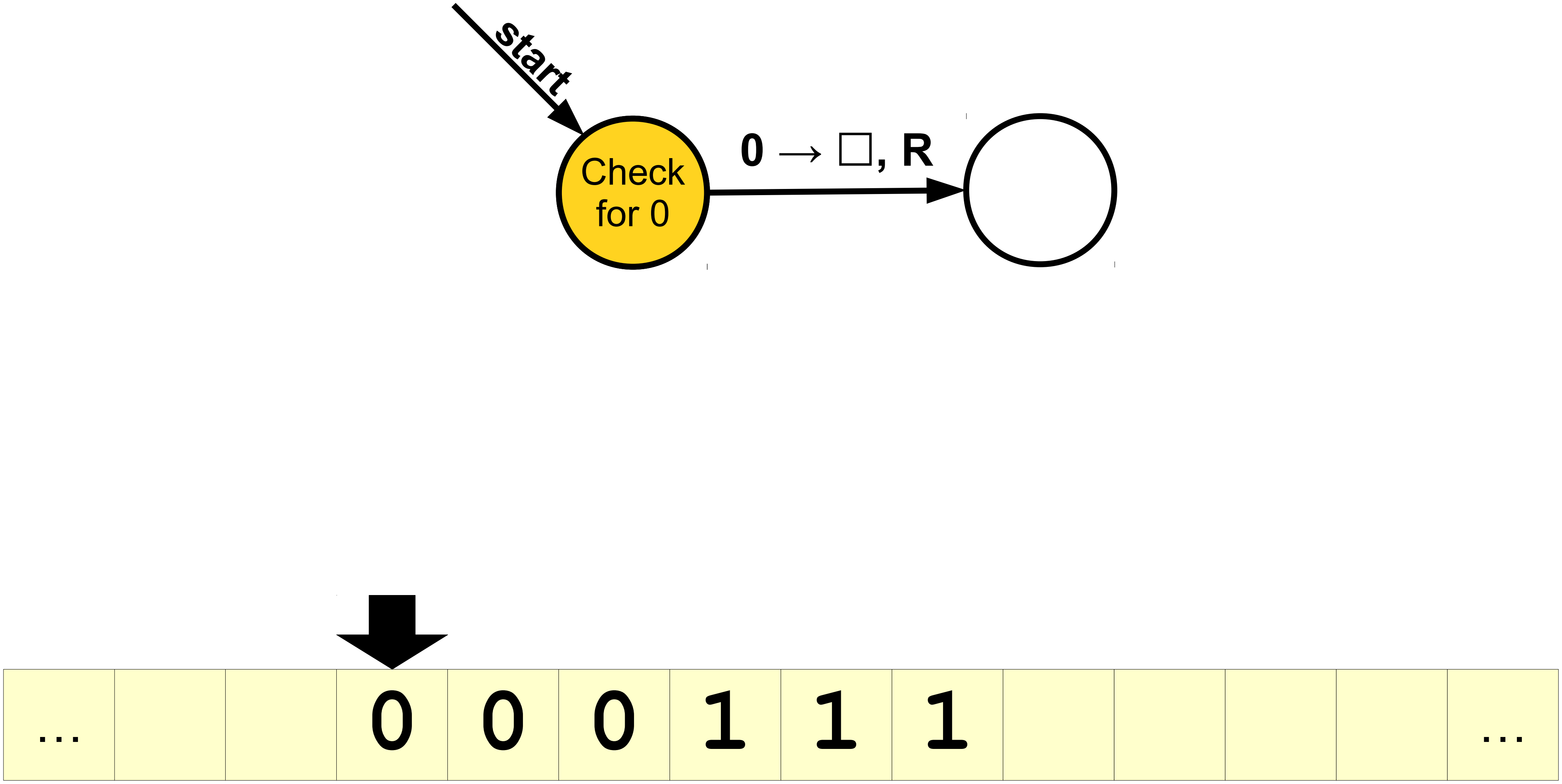


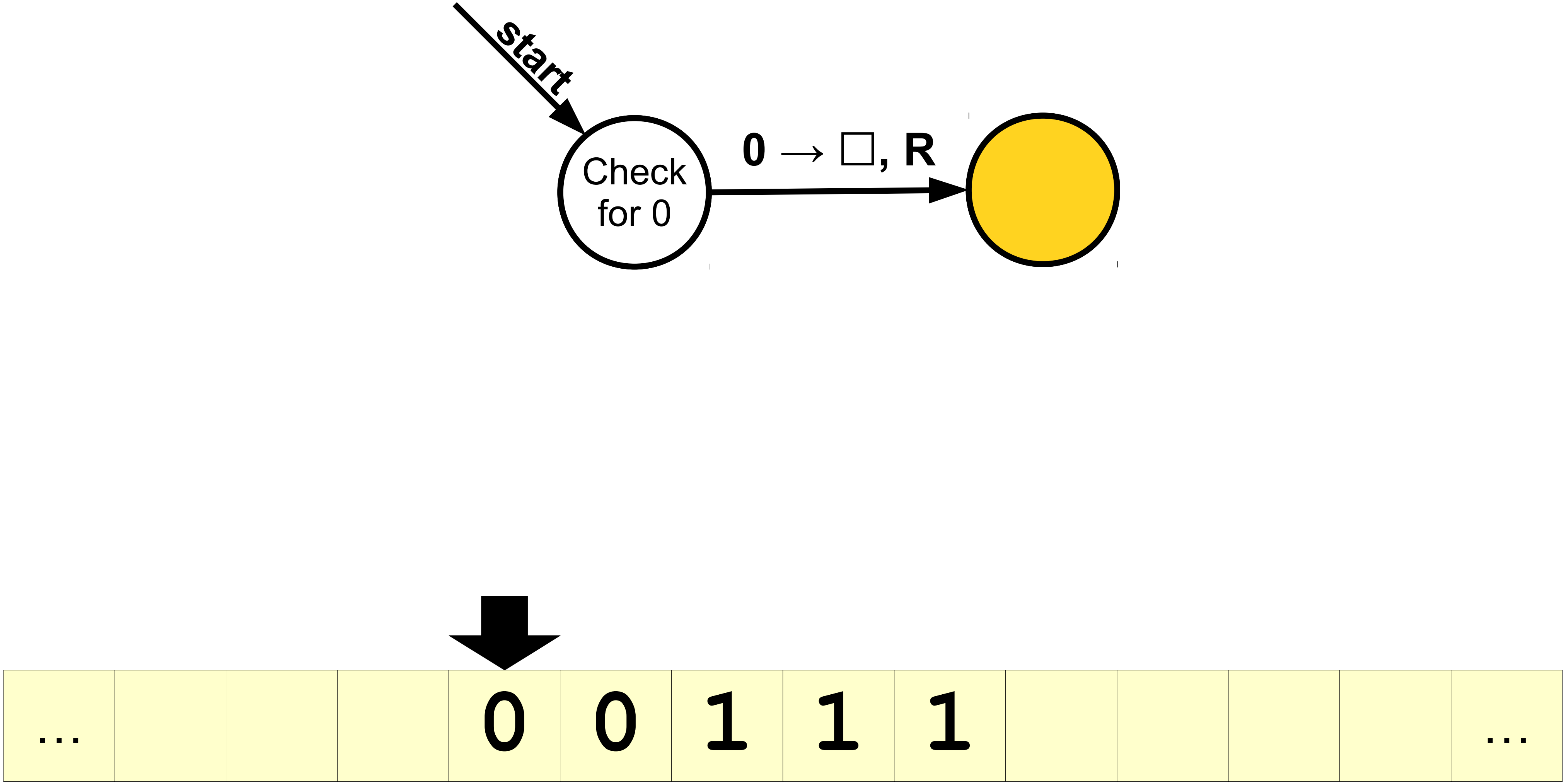
start

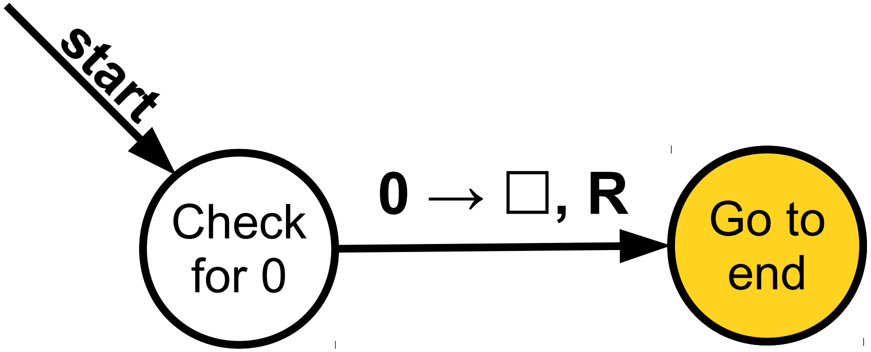

start
…
0
0
0
1
1
1
…

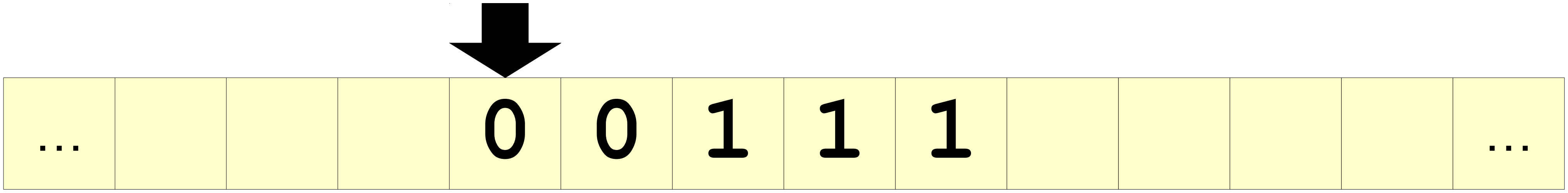

start
...
0
0
0
1
1
1
...

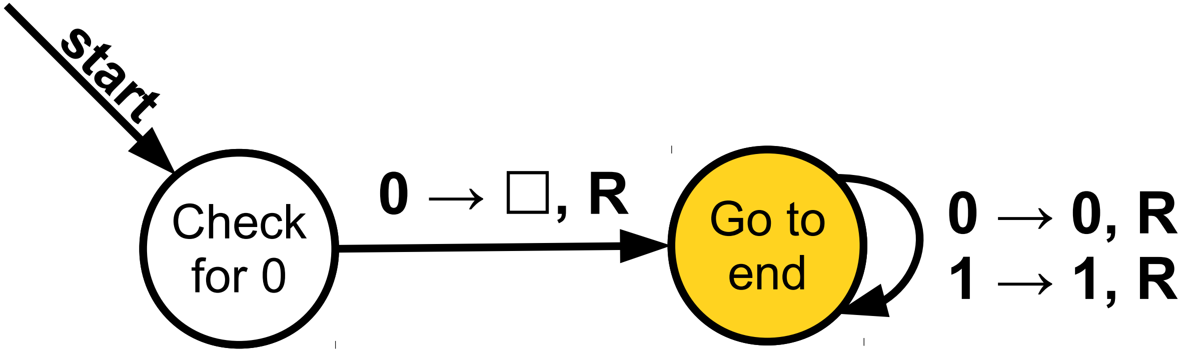

start
Check for 0
…
0
0
0
1
1
1
…


start
Check for 0
0 → □, R
…
0
0
0
1
1
1
…


start
Check for 0
0 → □, R
…
0
0
1
1
1
…


start
Check for 0
0 → □, R
Go to end


…
0
0
1
1
1
…



start

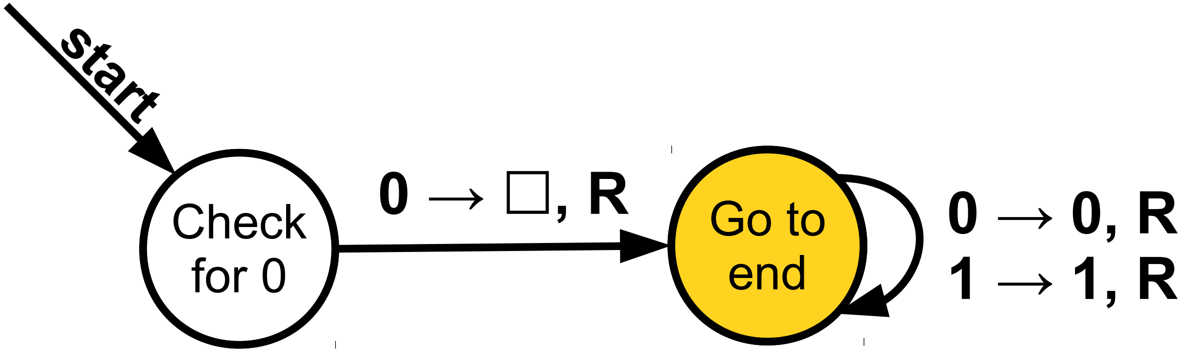
Check for 0

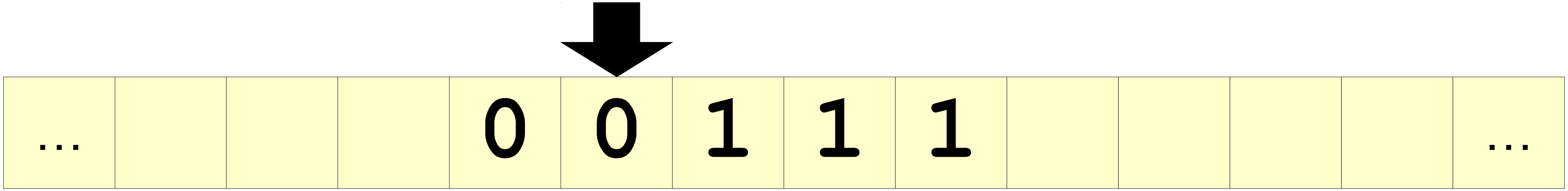
0 → □, R

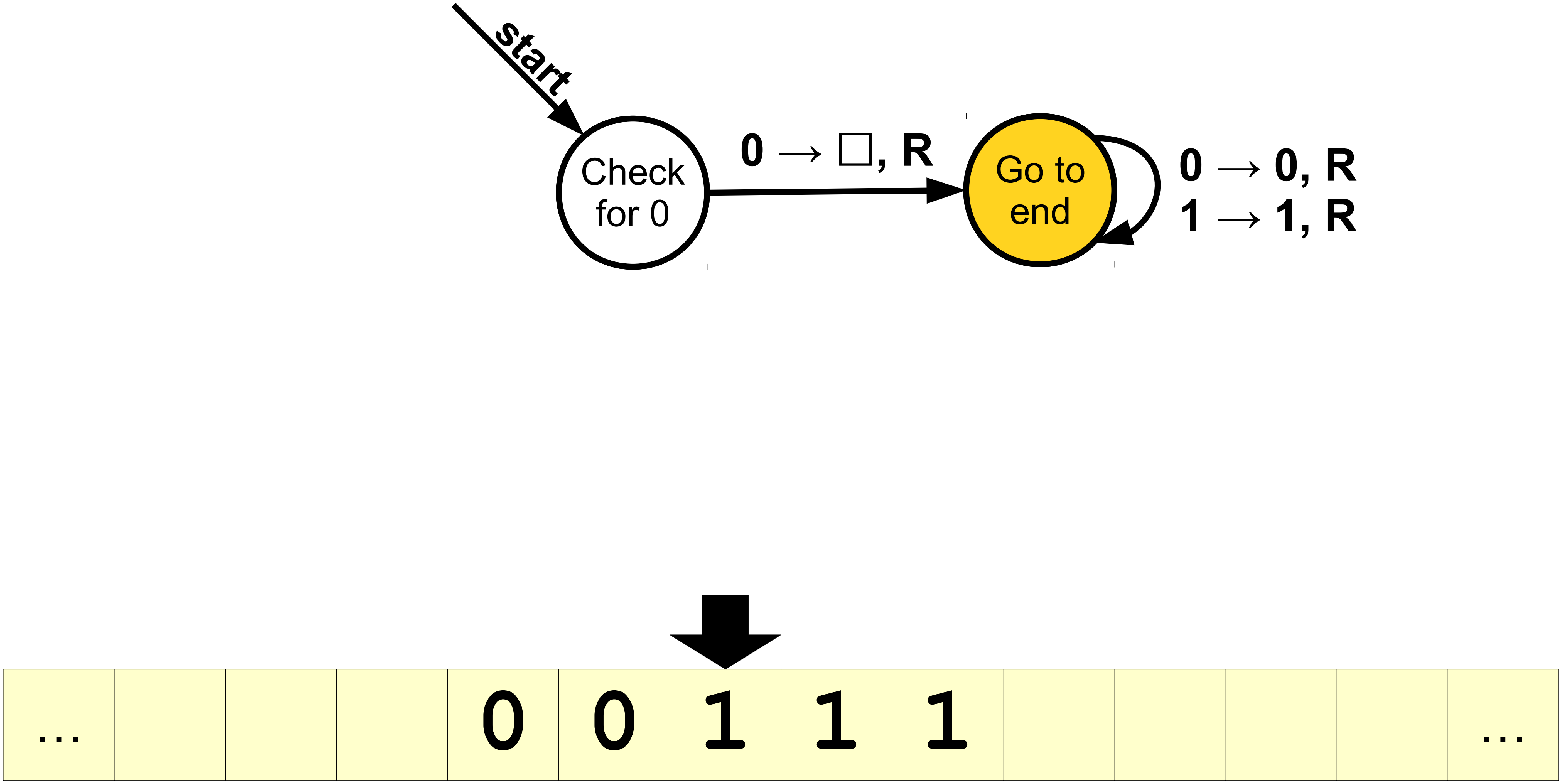
Go to end

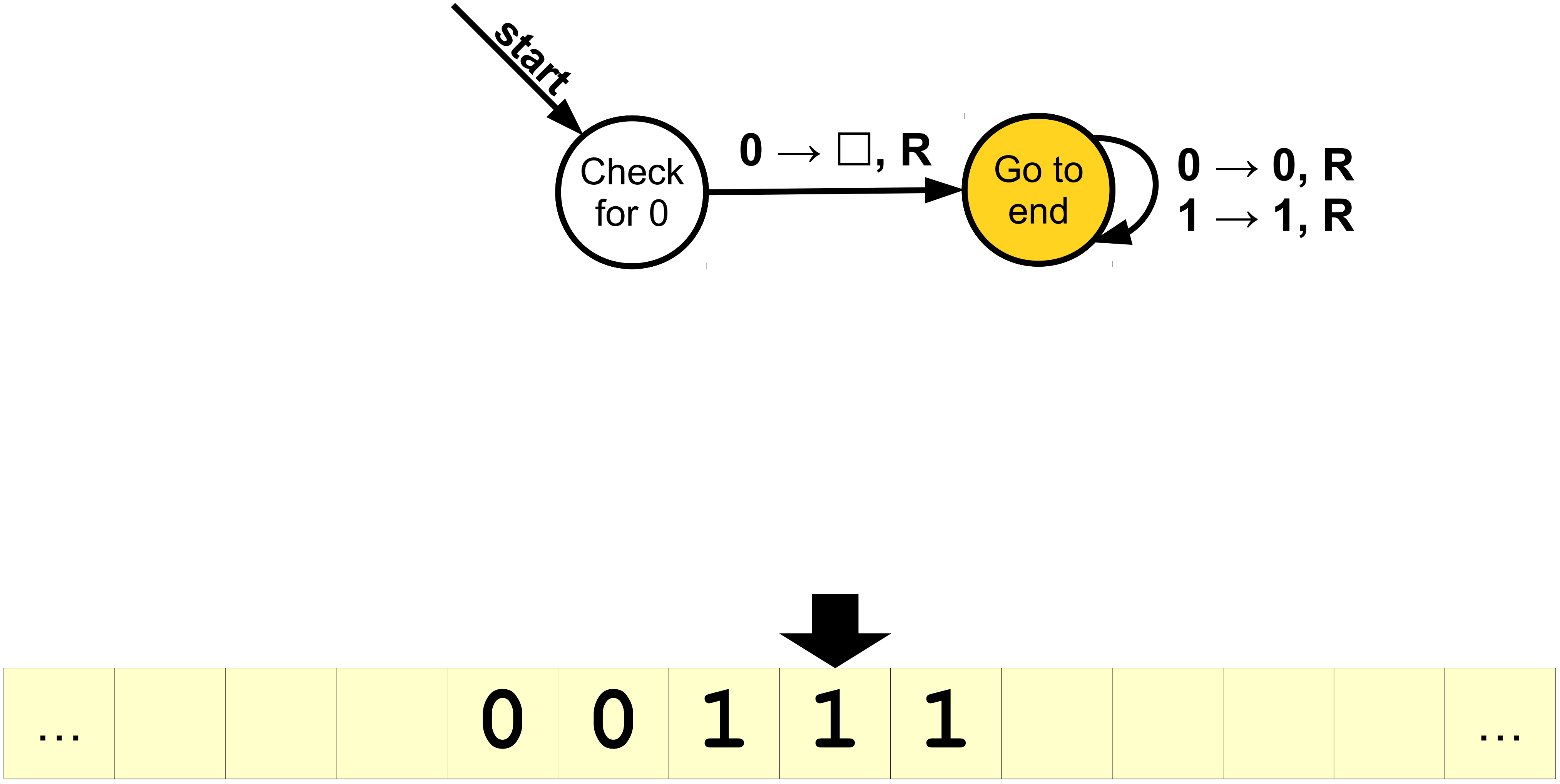
0 → 0, R
1 → 1, R

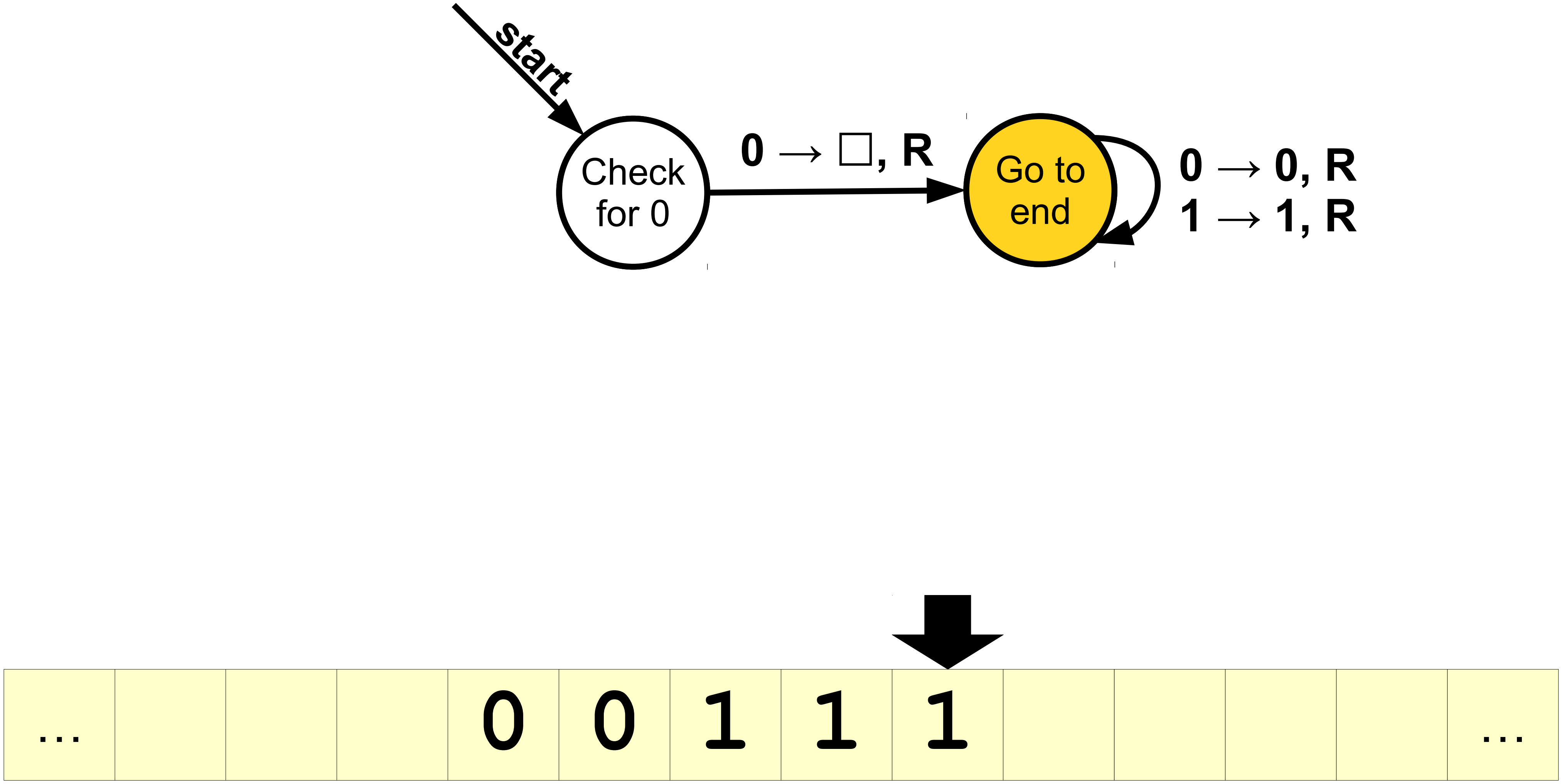
…				0	0	1	1	1					…

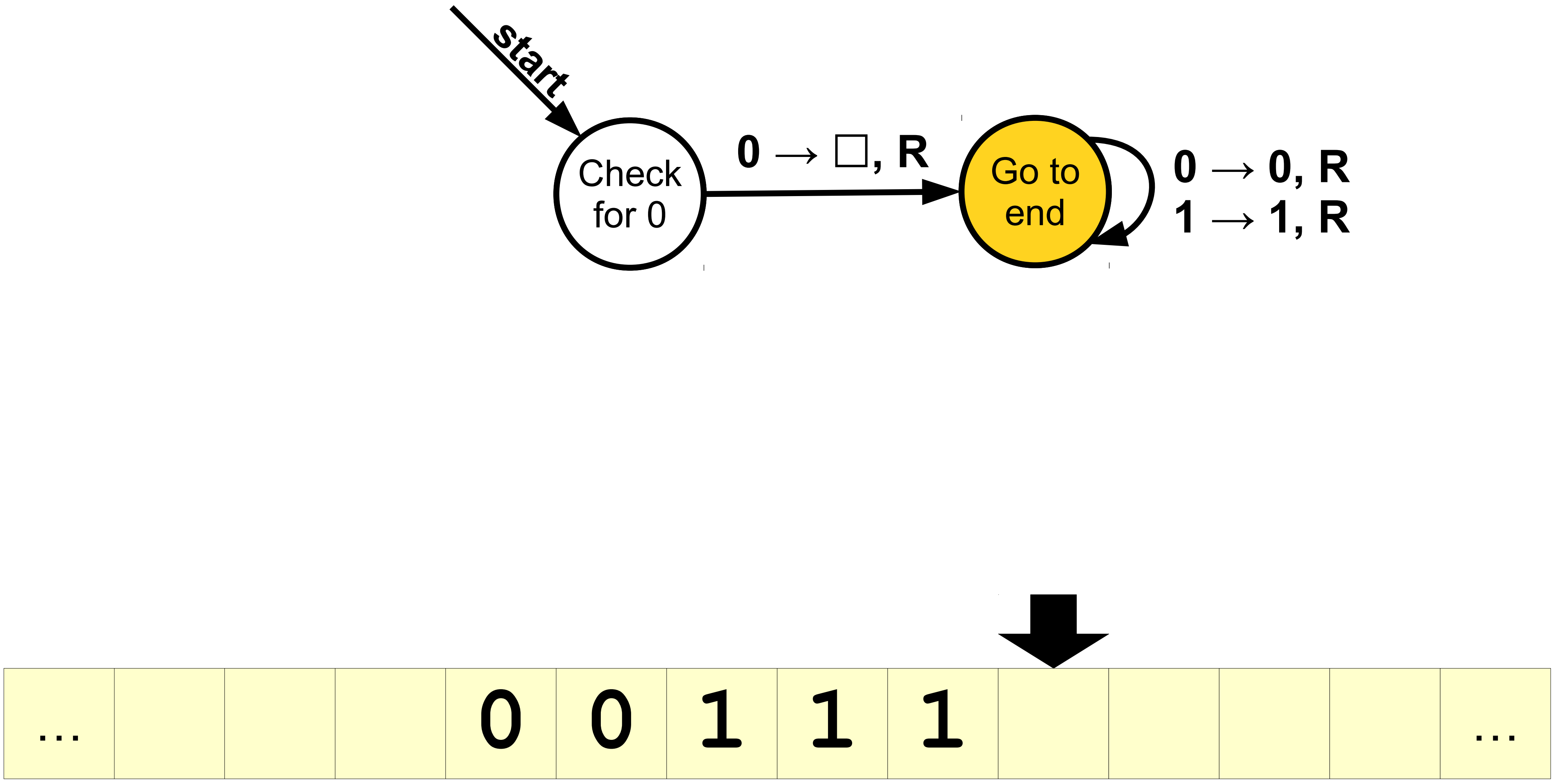

start
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R

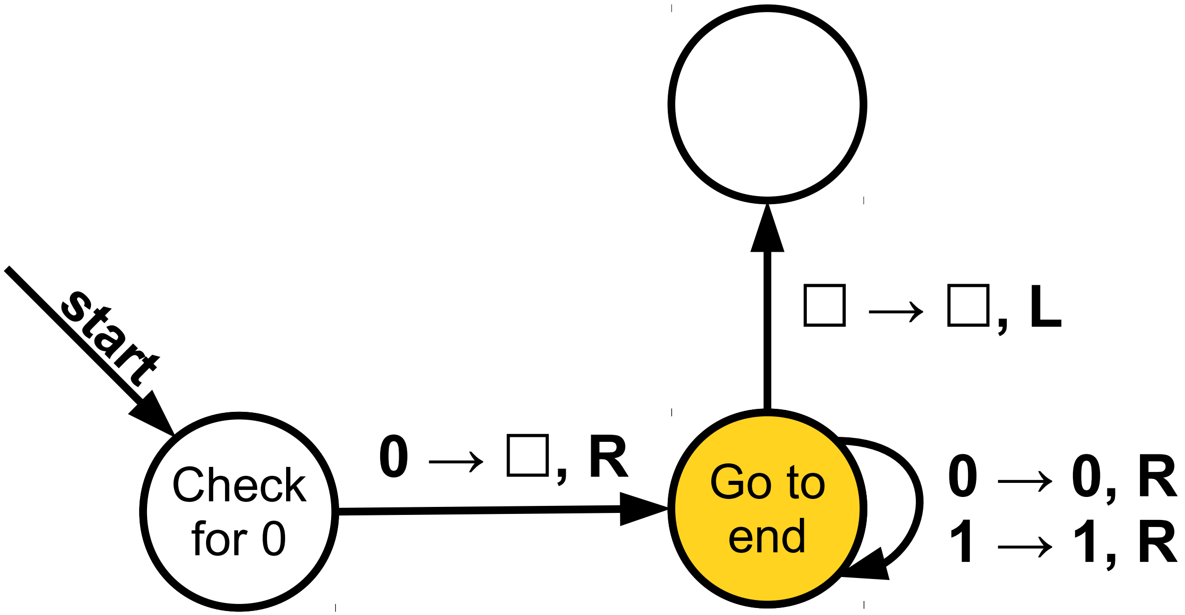

…
0
0
1
1
1
…

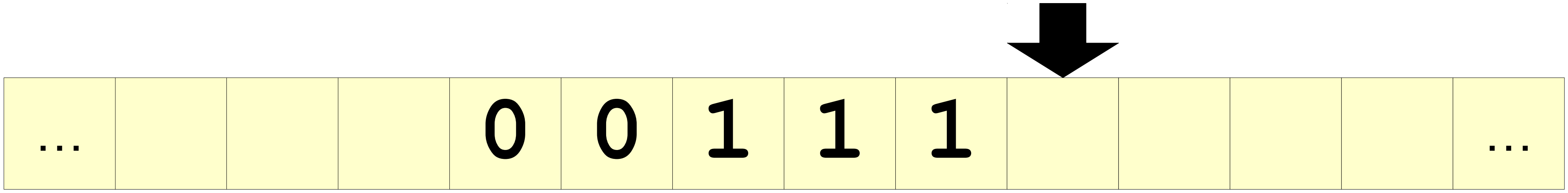

start
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
…
0
0
1
1
1
…

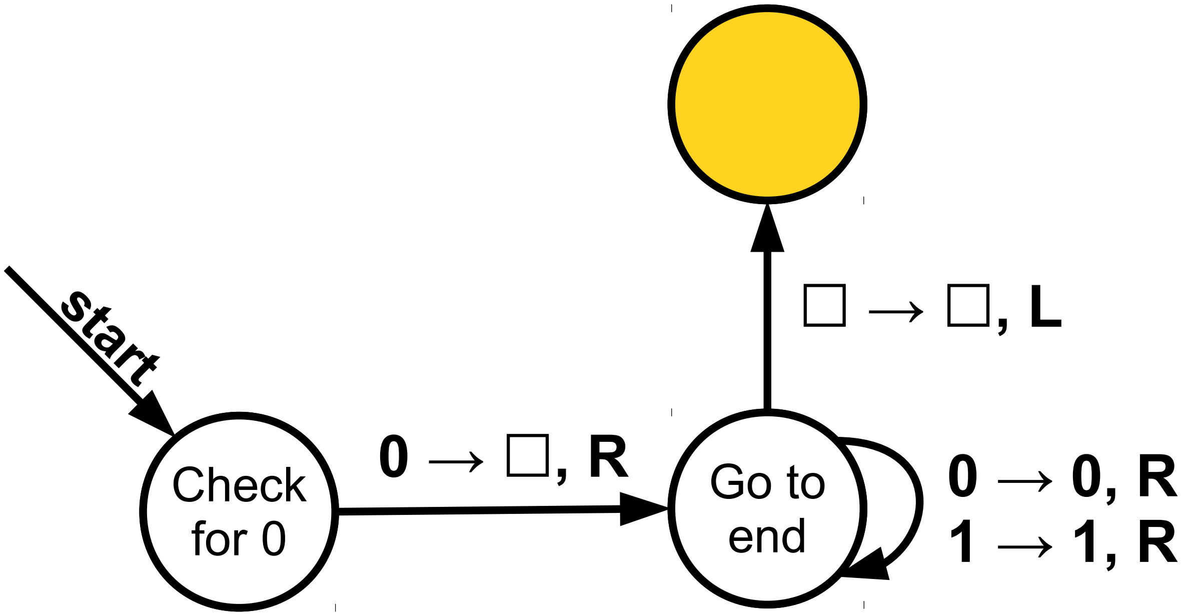

start
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
…
0
0
1
1
1
…

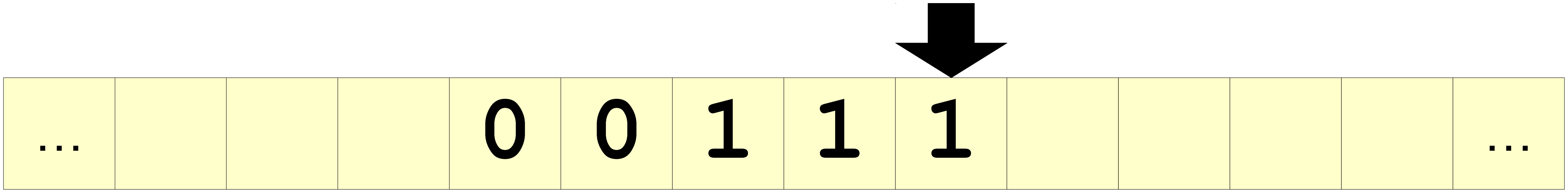

start
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
…
0
0
1
1
1
…

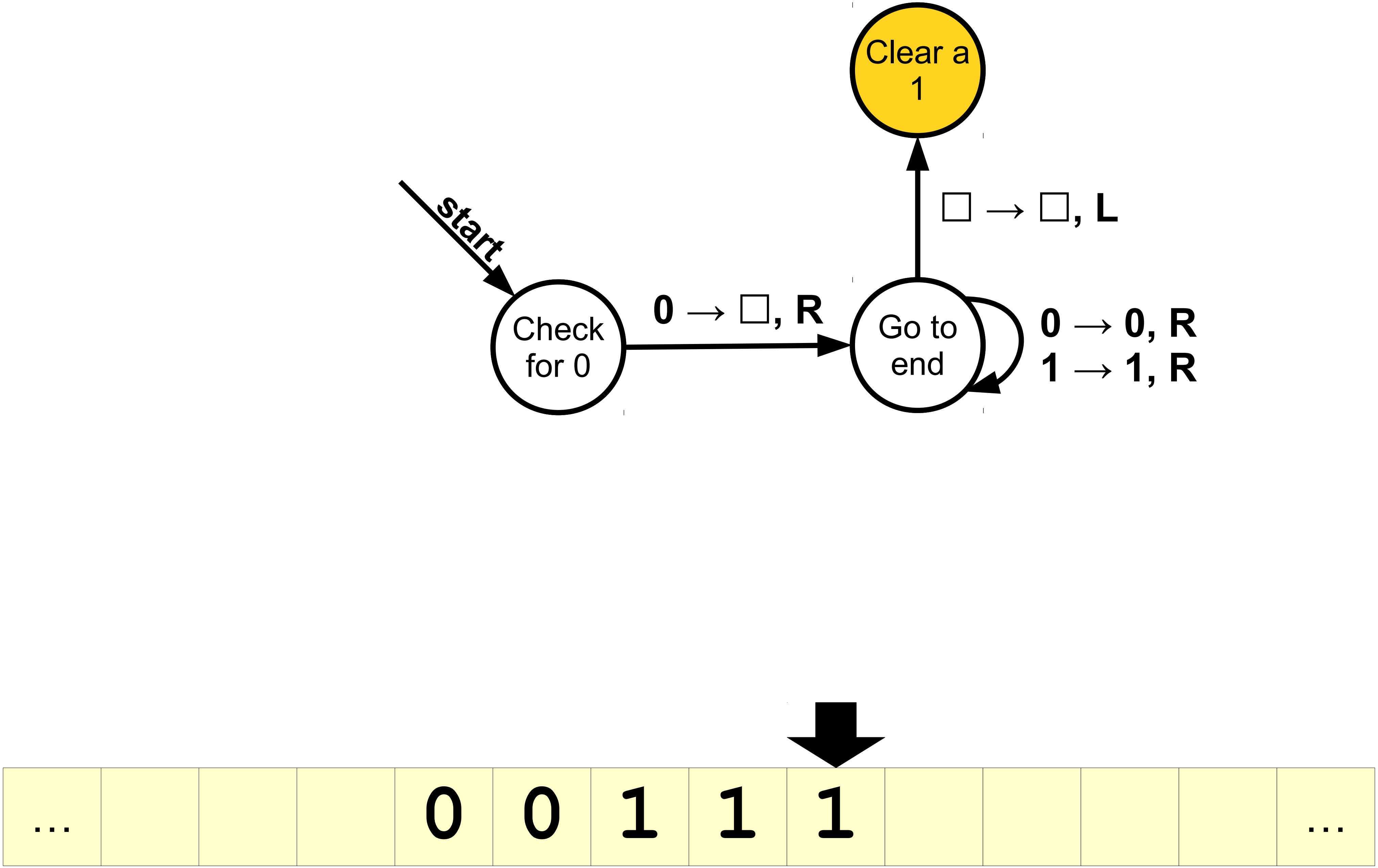

start
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
…
0
0
1
1
1
…

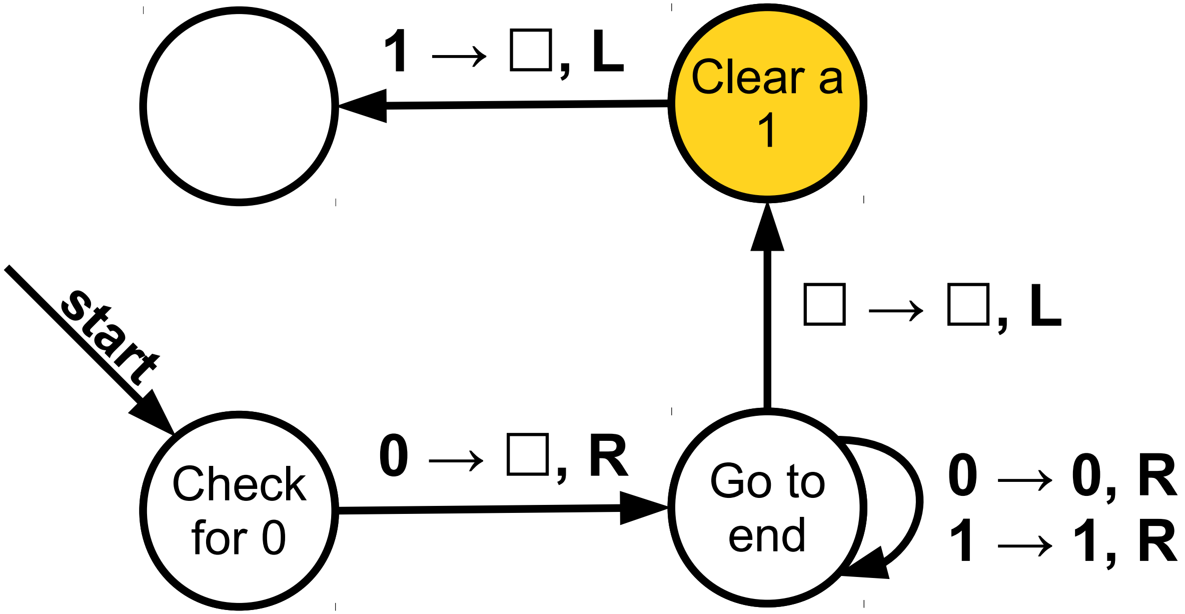

start
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, L

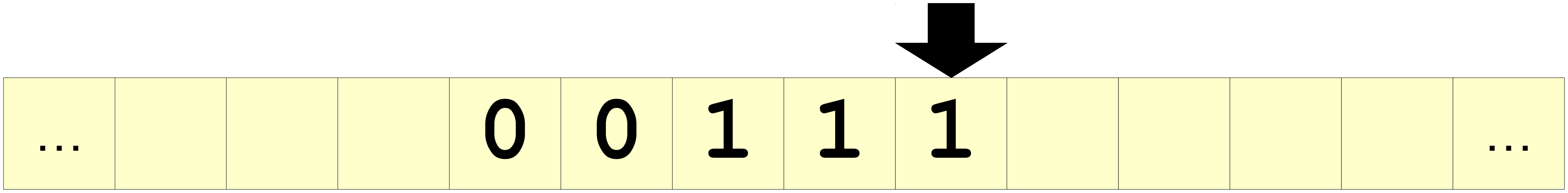

…
0
0
1
1
1
…

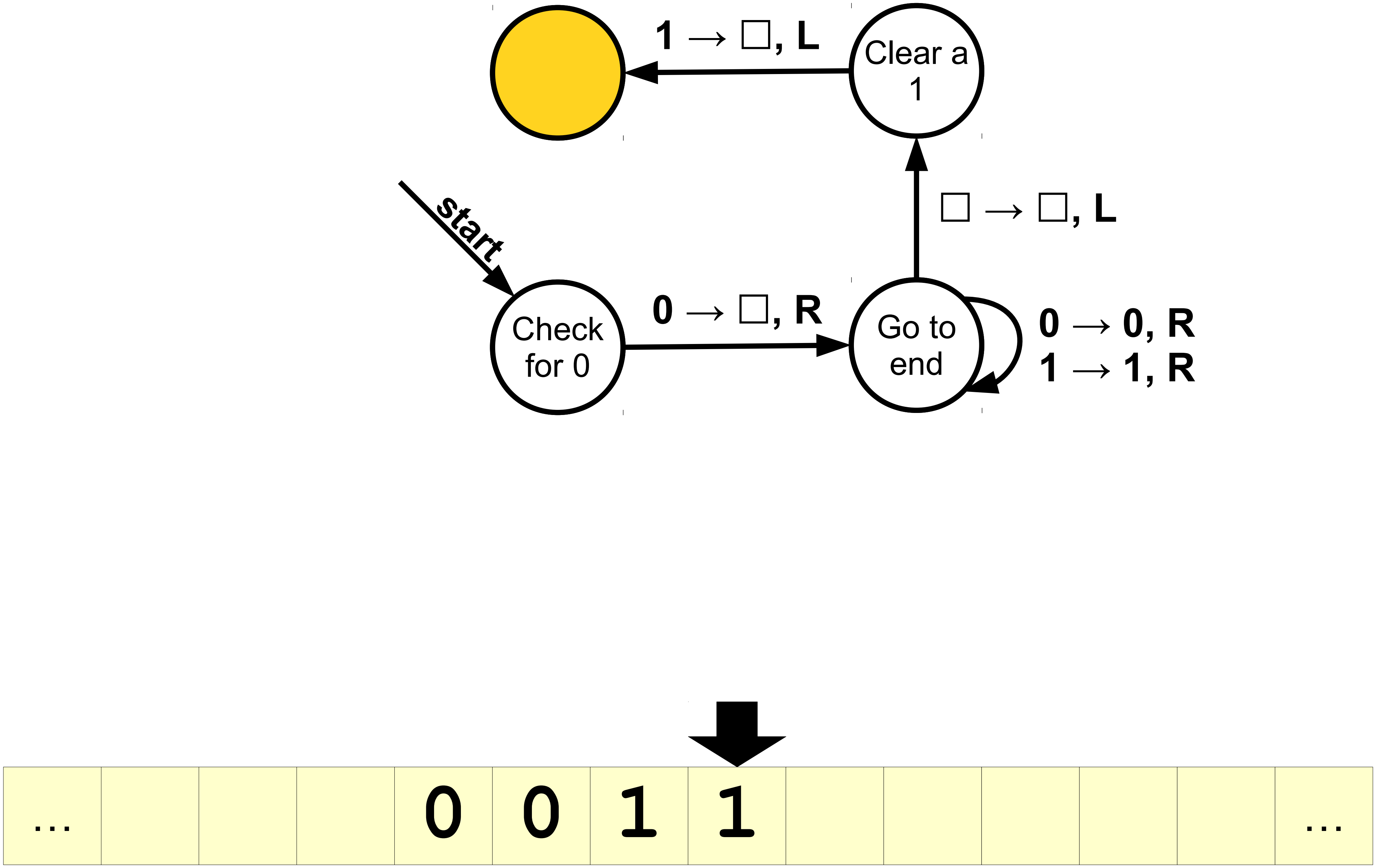

start
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, L

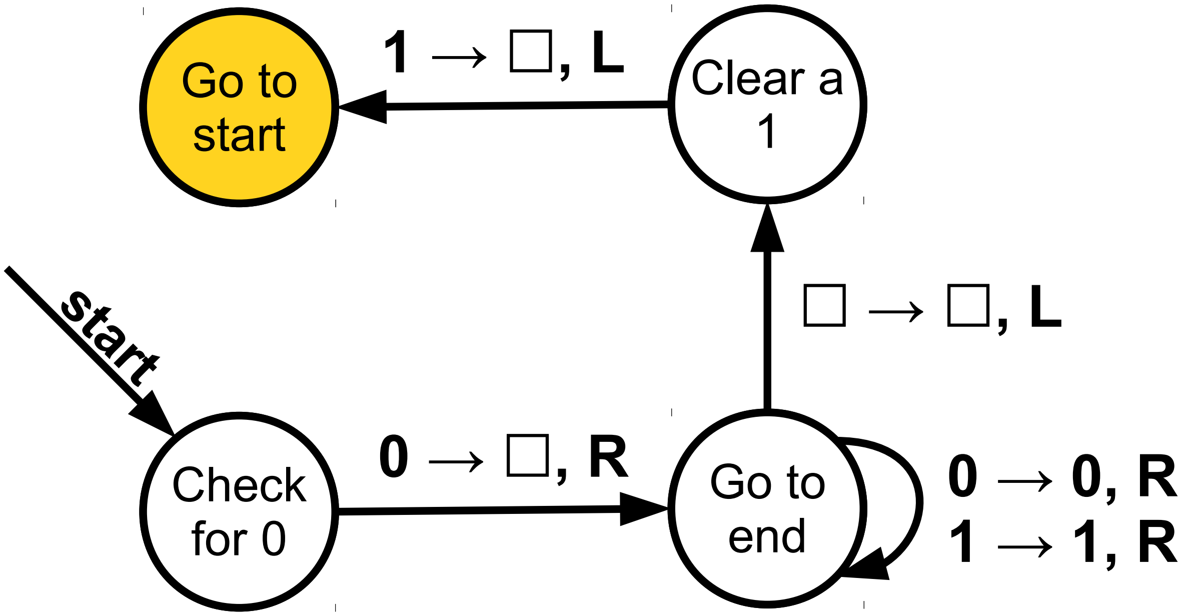

…
0
0
1
1
1
…

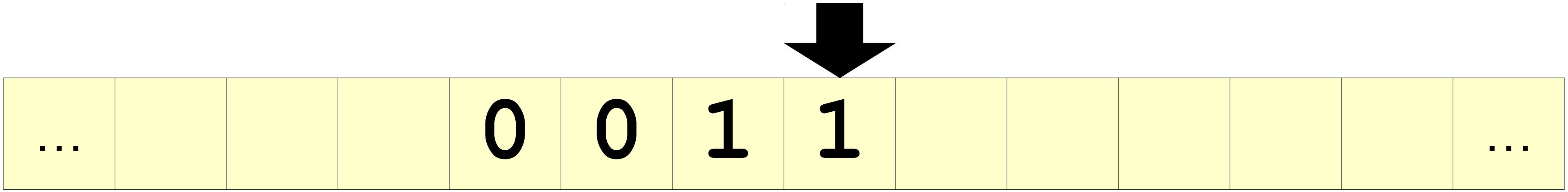

start
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, L
Clear a 1
…
0
0
1
1
1
…

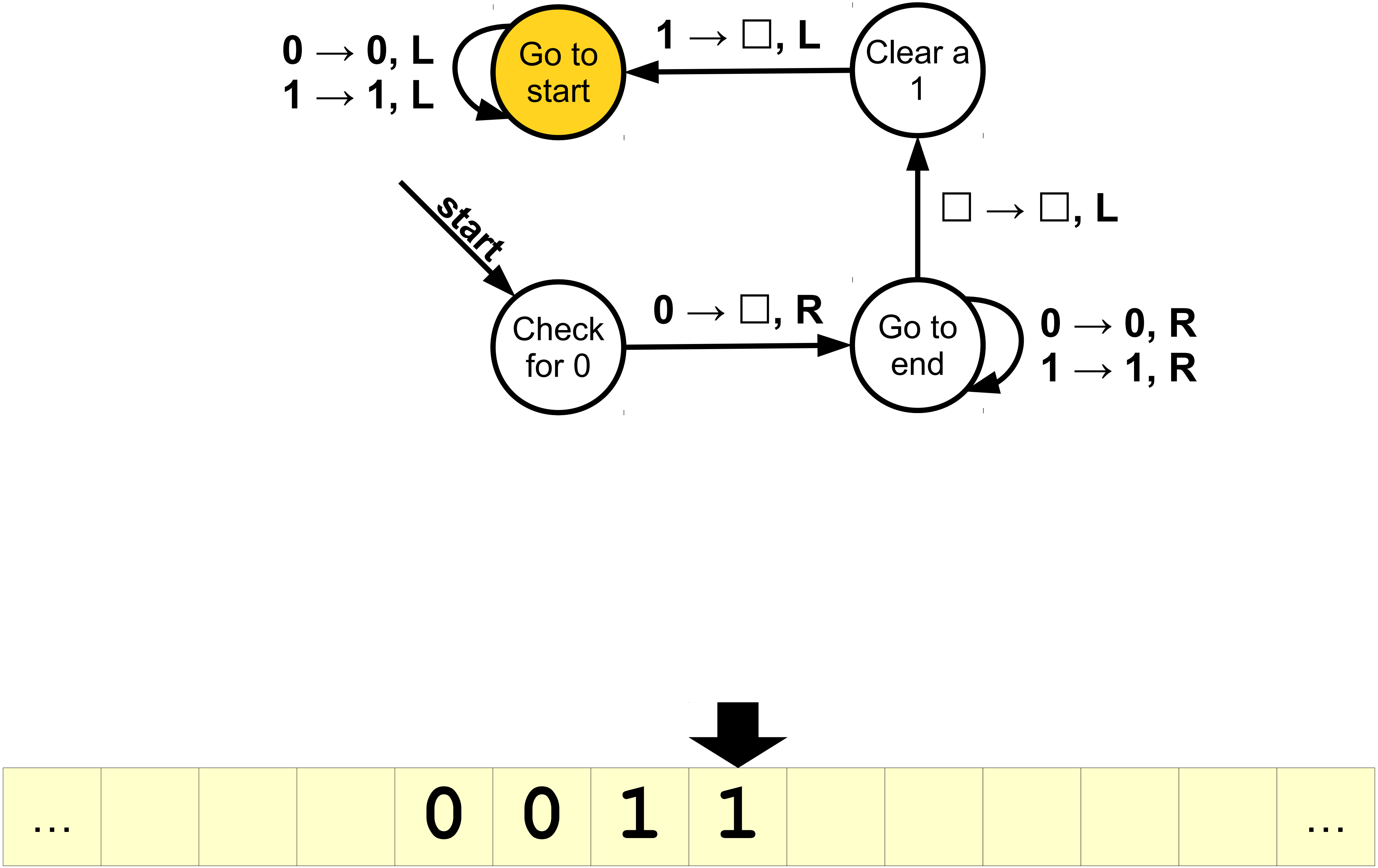

1 → □, L
Clear a 1
start
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R

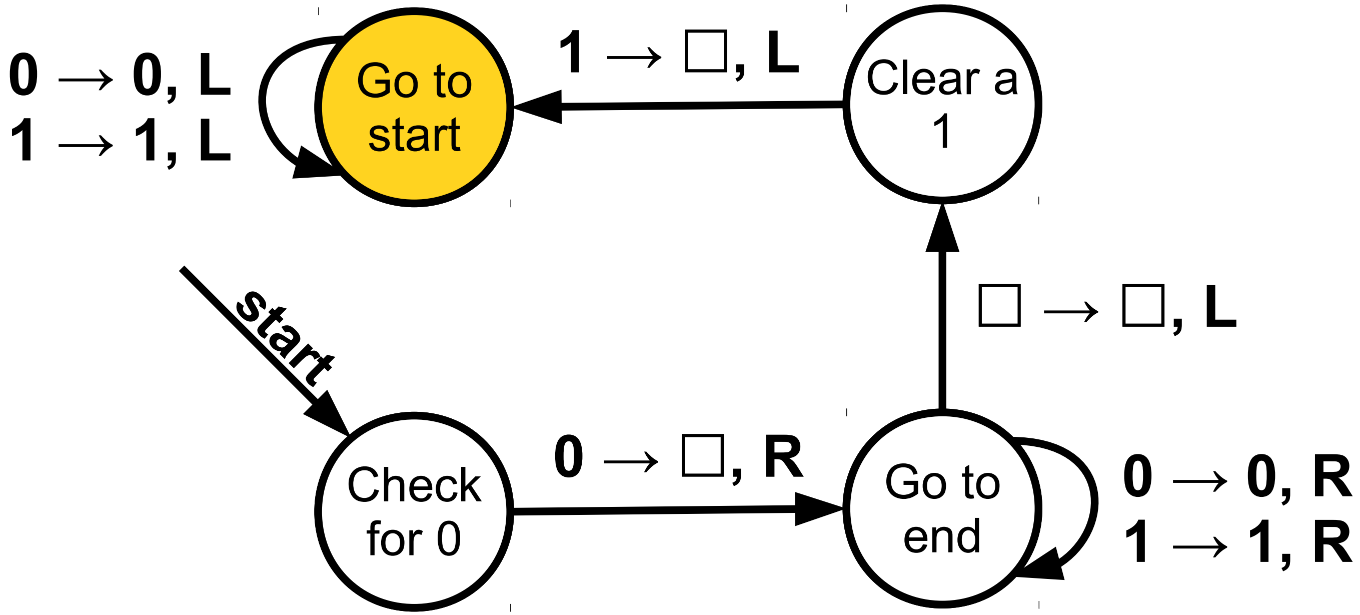

…
0
0
1
1
1
…

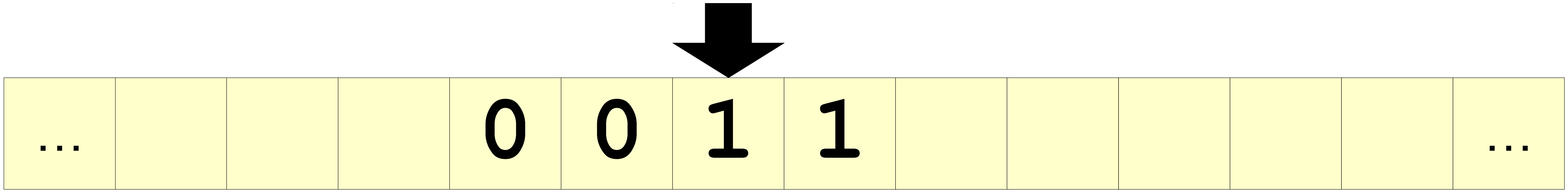

1 → □, L
Clear a 1
start
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
…
0
0
1
1
…


Go to start
1 → □, L
Clear a 1
start
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R

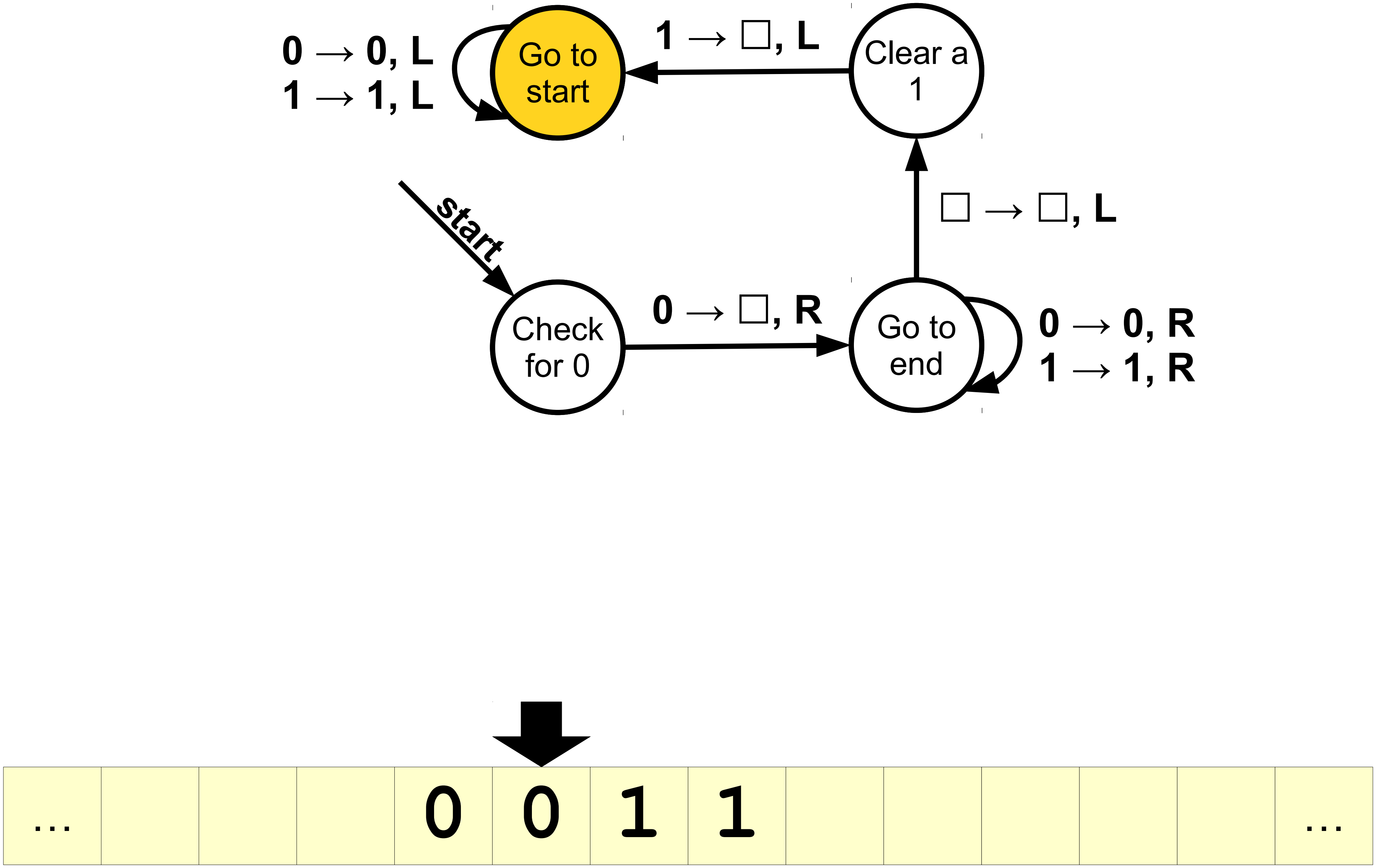

…
0
0
1
1
…


0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
…
0
0
1
1
…

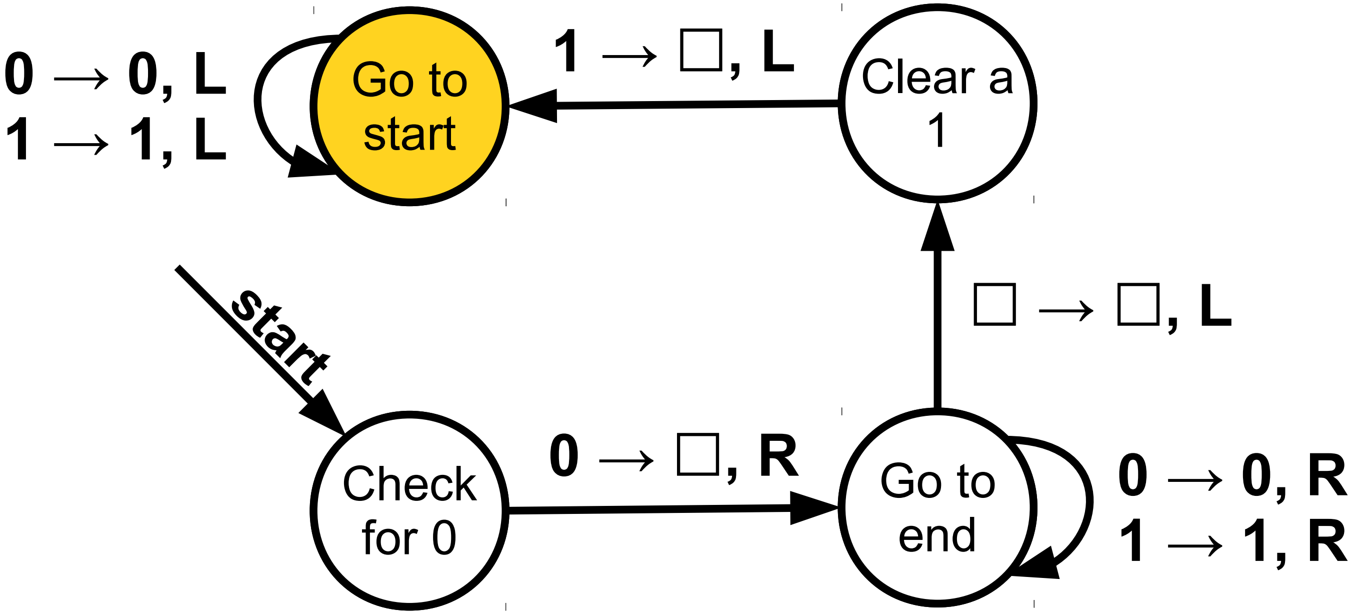

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R

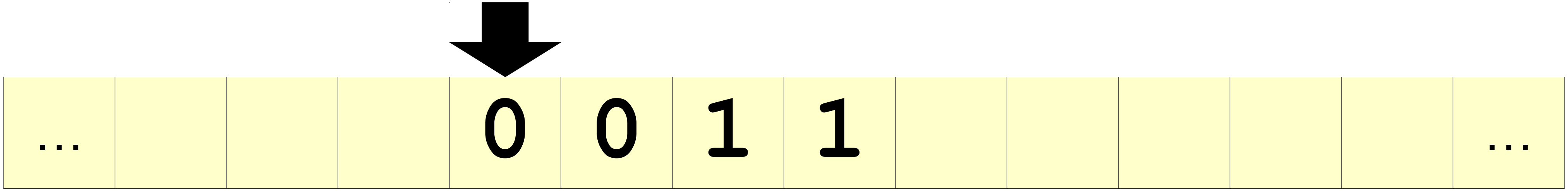


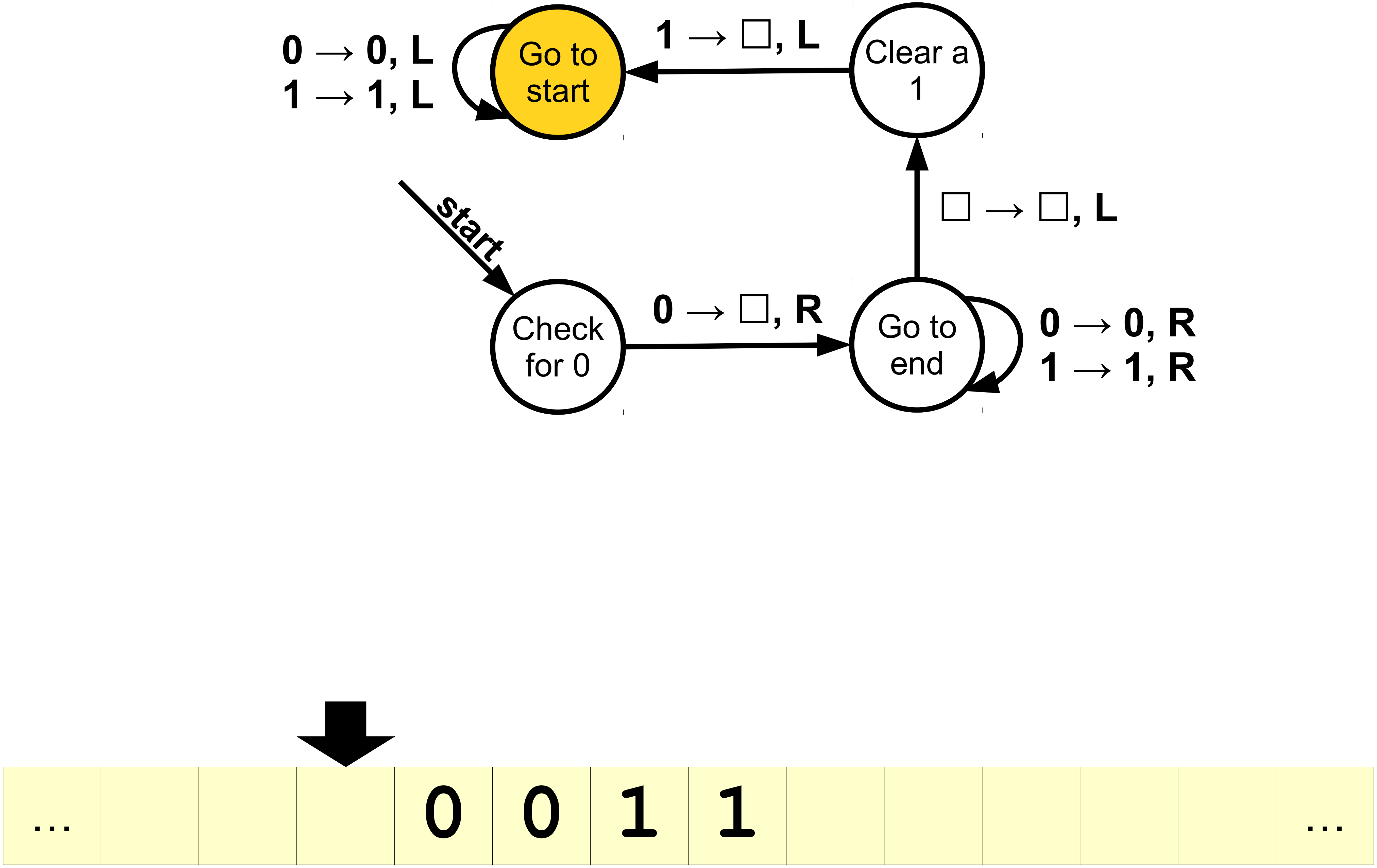
…				0	0	1	1						…



0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
…
0
0
1
1
…


0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R


…
0
0
1
1
…



Go to start

0 → 0, L
1 → 1, L

1 → □, L

Clear a 1

□ → □, L

start

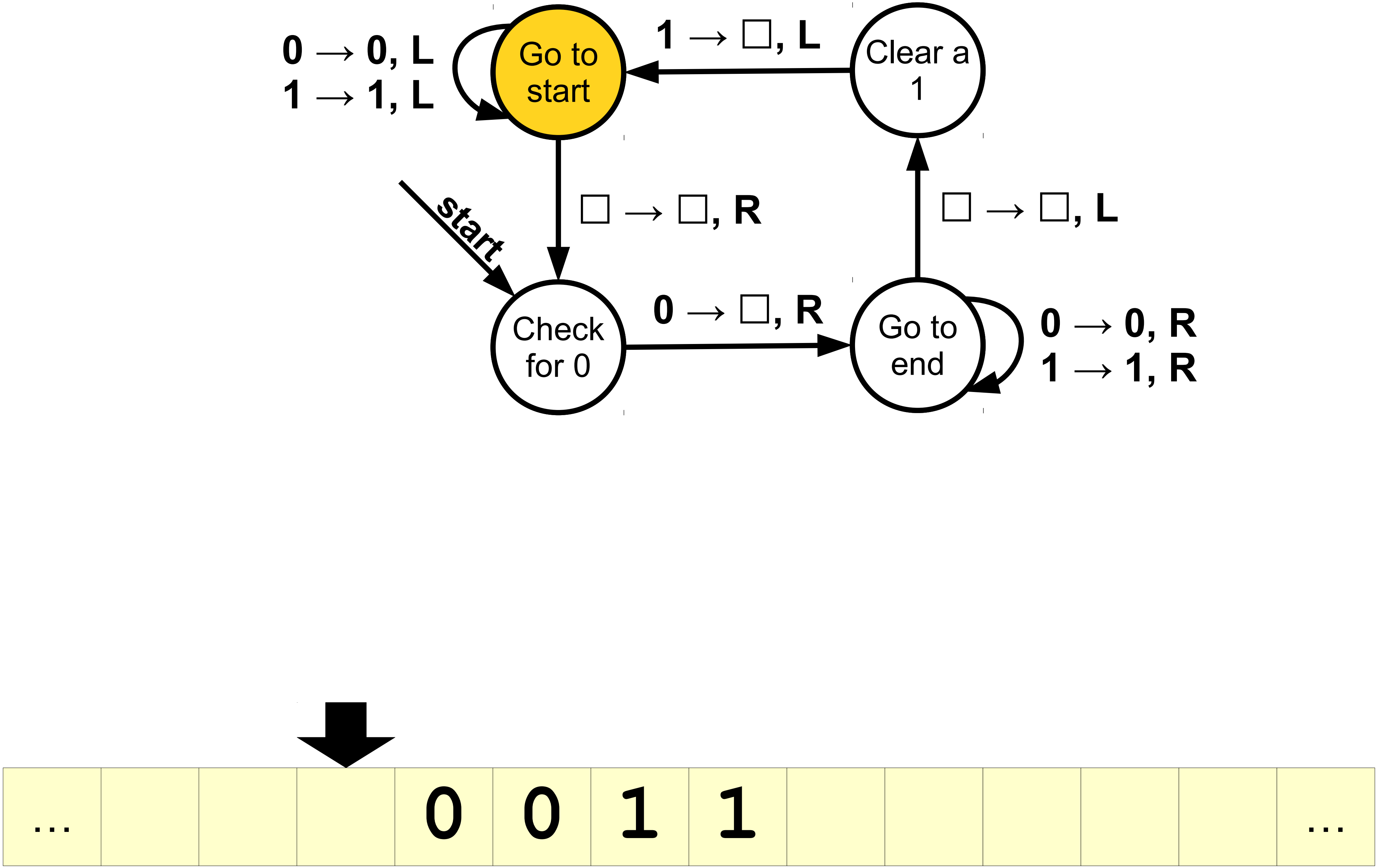
Check for 0

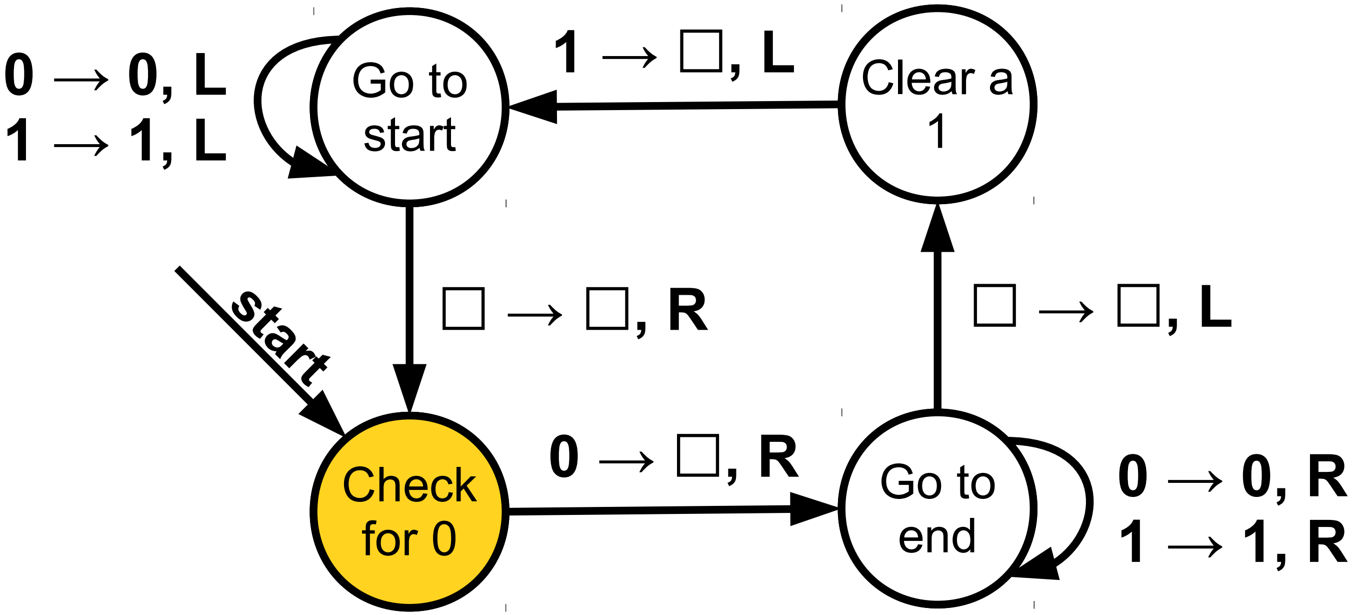
0 → □, R

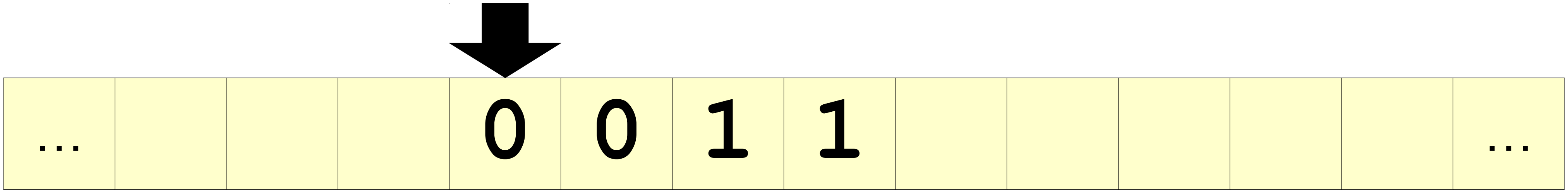
Go to end

0 → 0, R
1 → 1, R

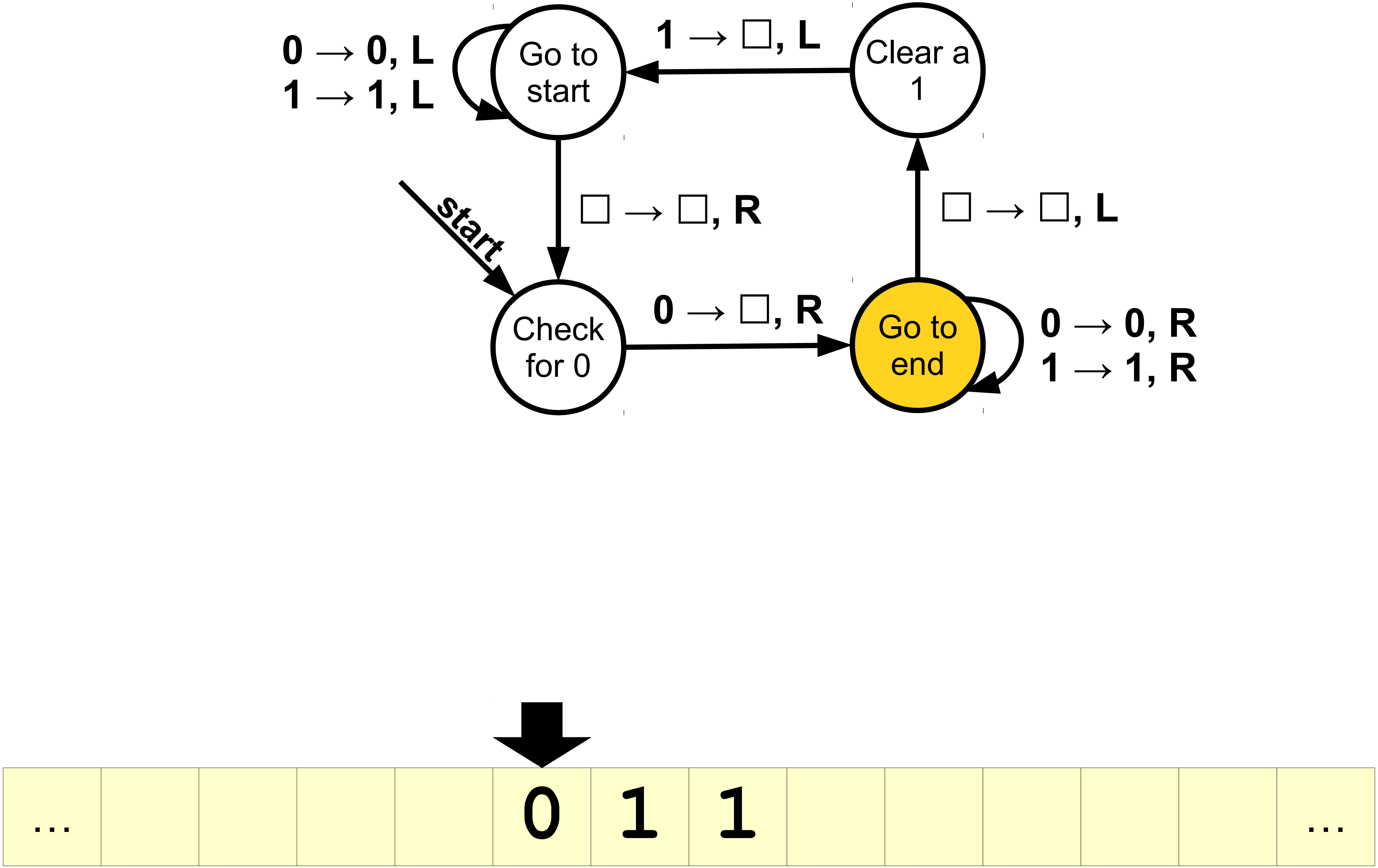
… 0 0 1 1 …

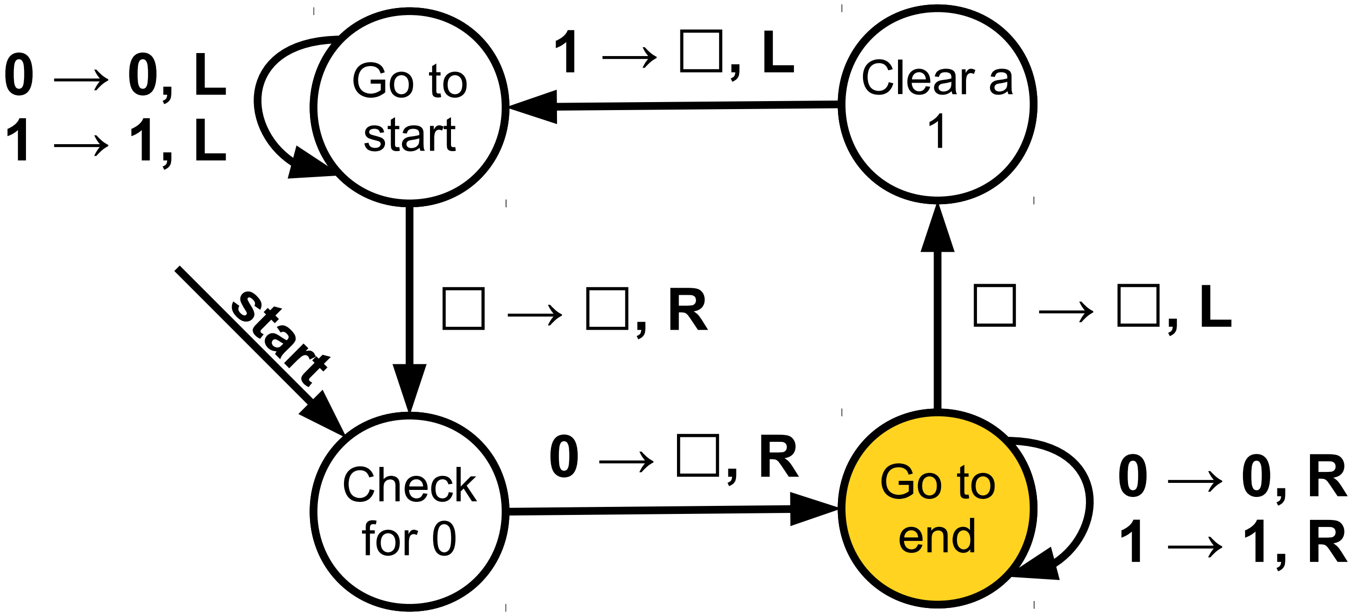

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
...
0
0
1
1
...

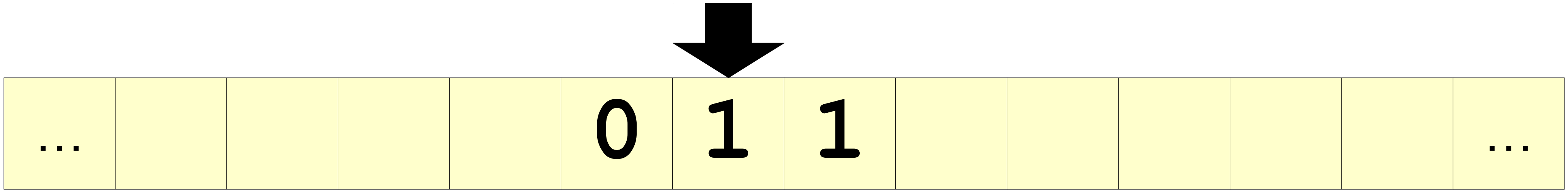

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R

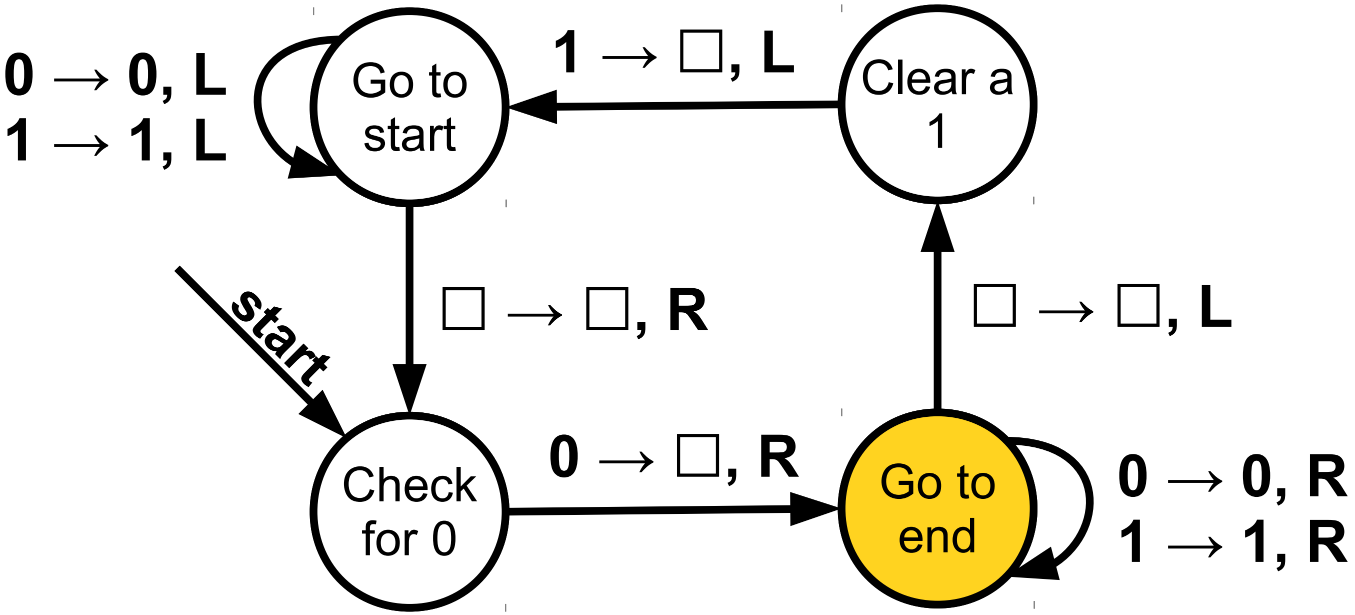


…				0	0	1	1						…


0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
…
0
1
1
…


0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R


…
0
1
1
…



Go to start

Check for 0

Go to end

Clear a 1

start

0 → 0, L
1 → 1, L

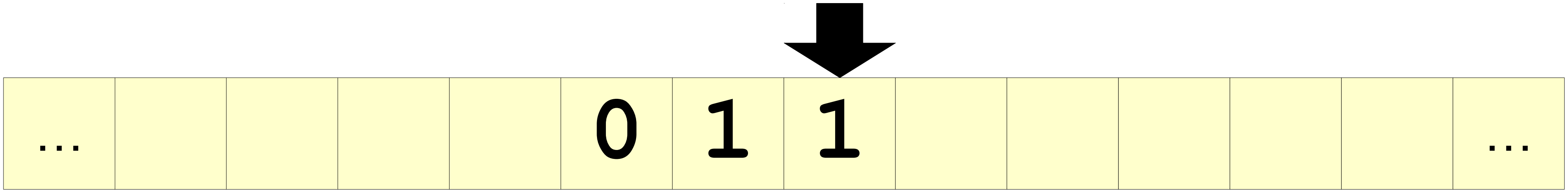
□ → □, R

0 → □, R

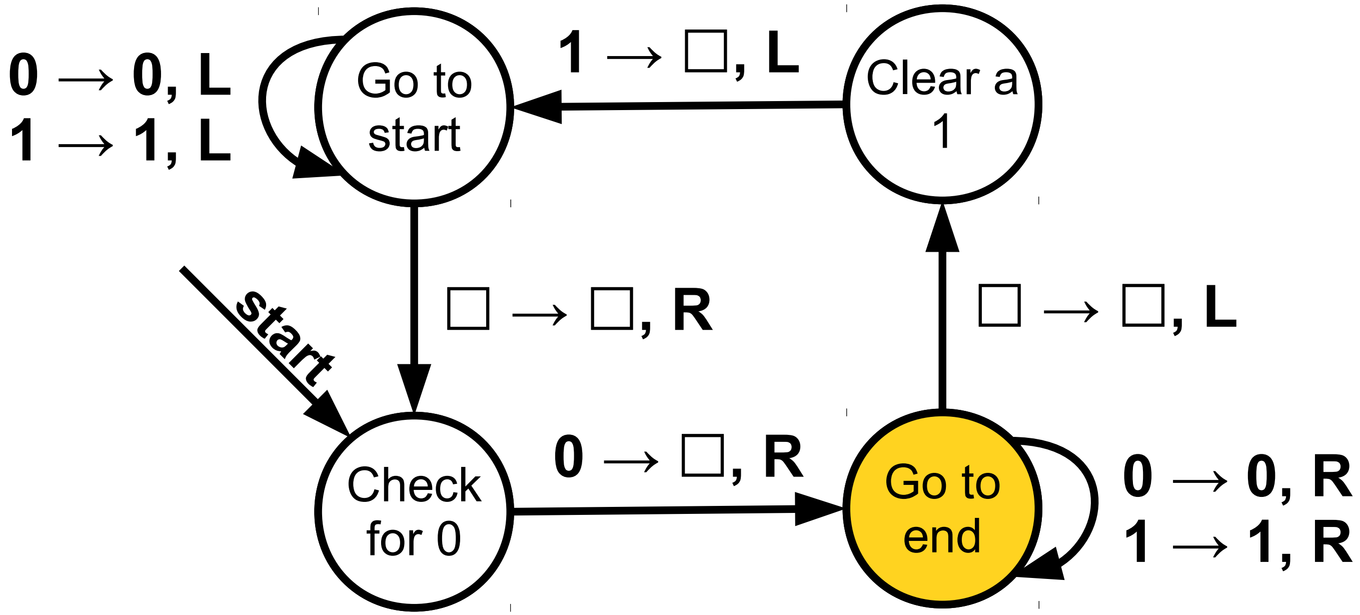
0 → 0, R
1 → 1, R

□ → □, L

1 → □, L



…					0	1	1						…



0 → 0, L
1 → 1, L

Go to start

1 → □, L

Clear a 1

start

□ → □, R

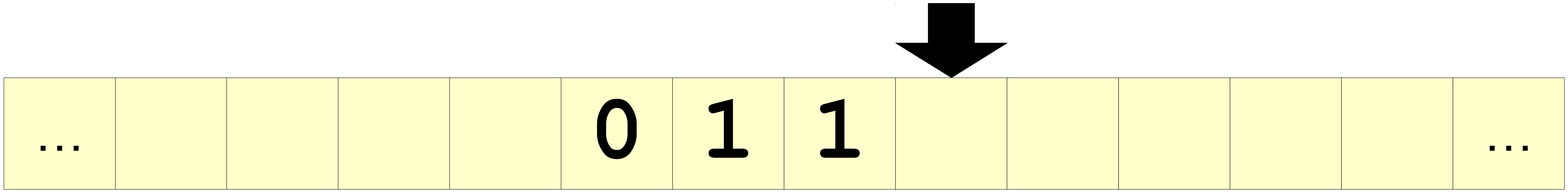
□ → □, L

Check for 0

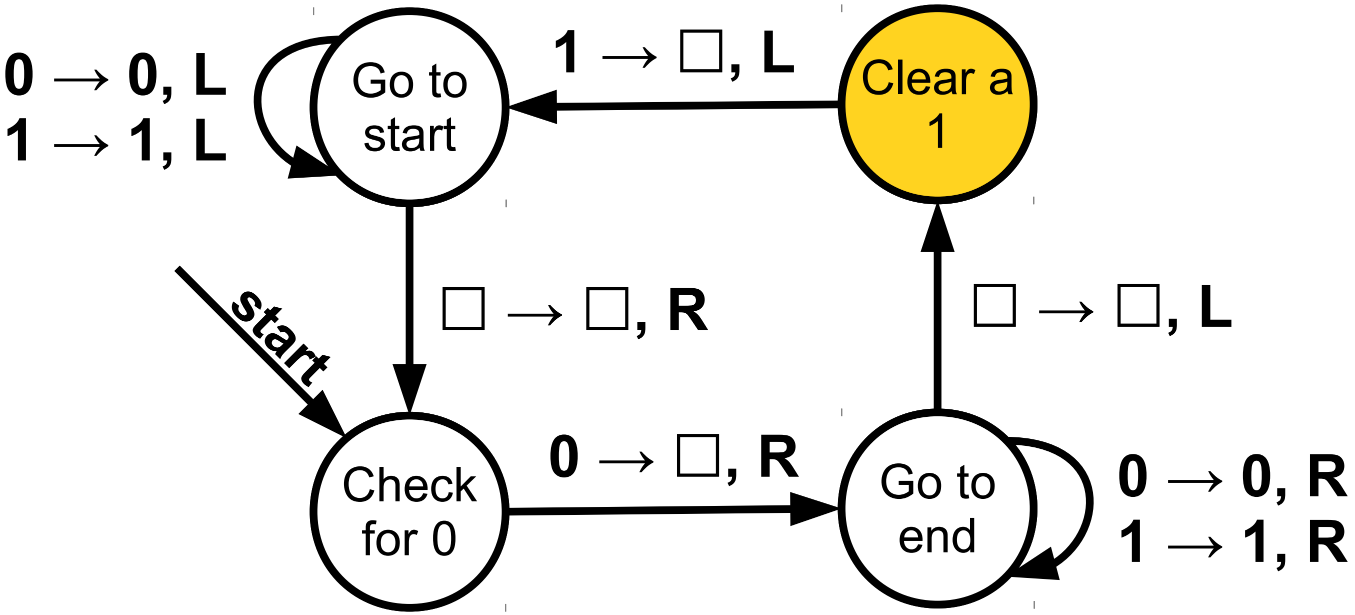
0 → □, R

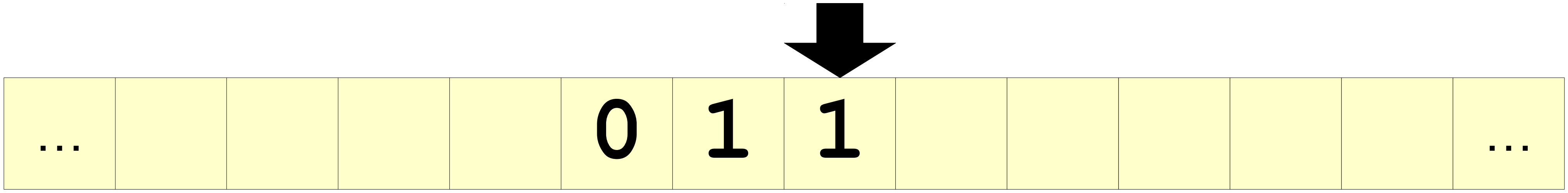
Go to end

0 → 0, R
1 → 1, R

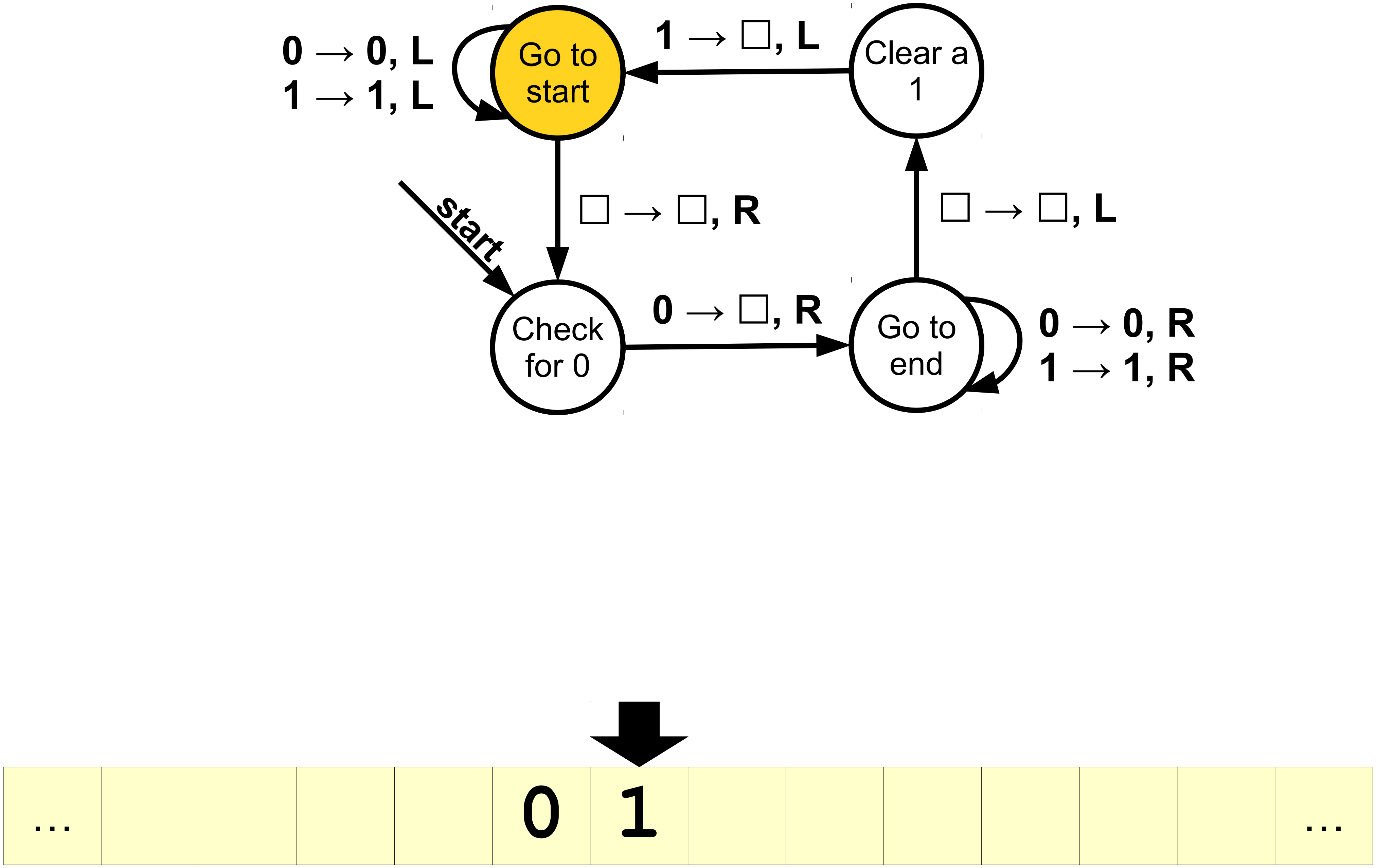


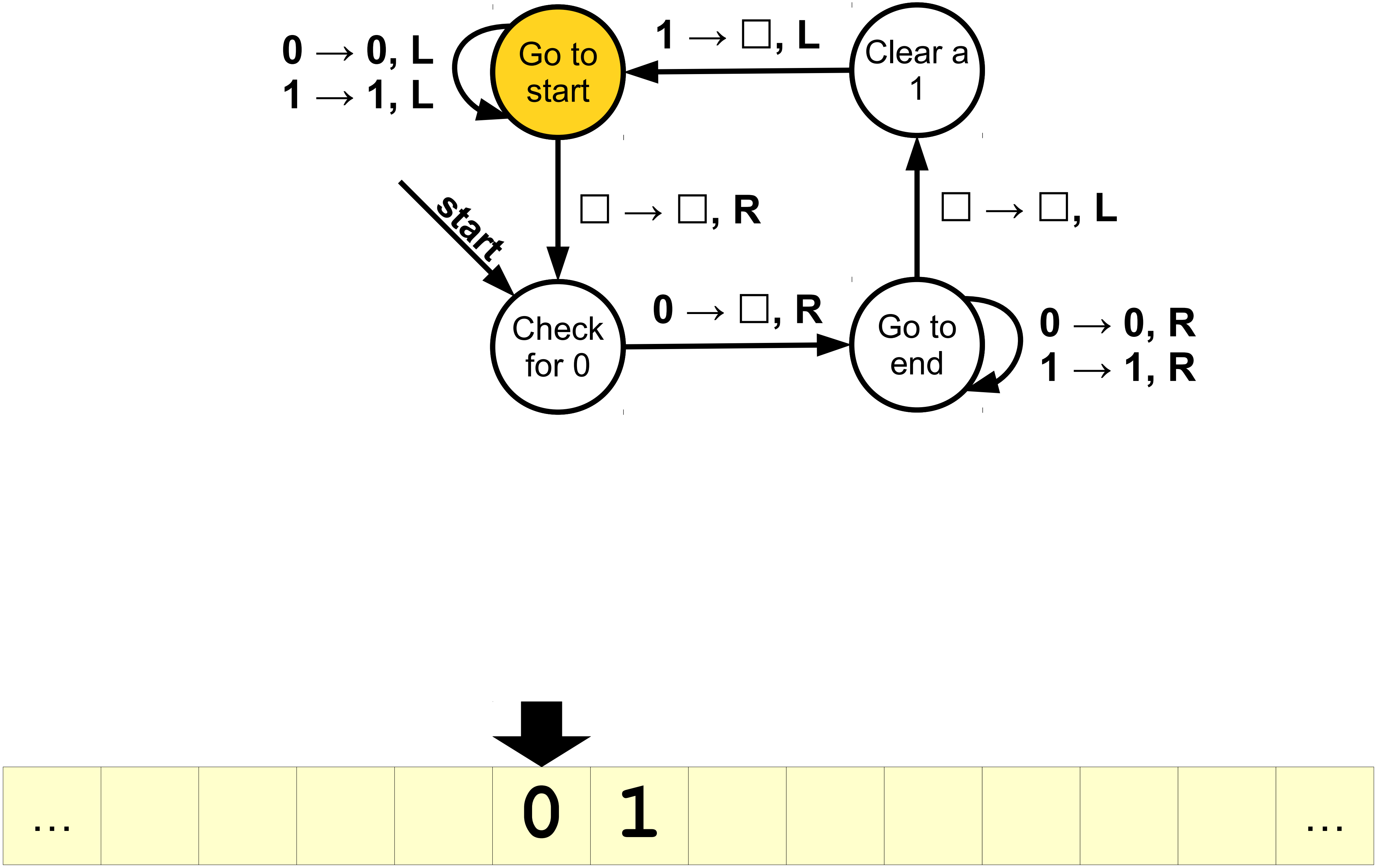
… 0 1 1 …

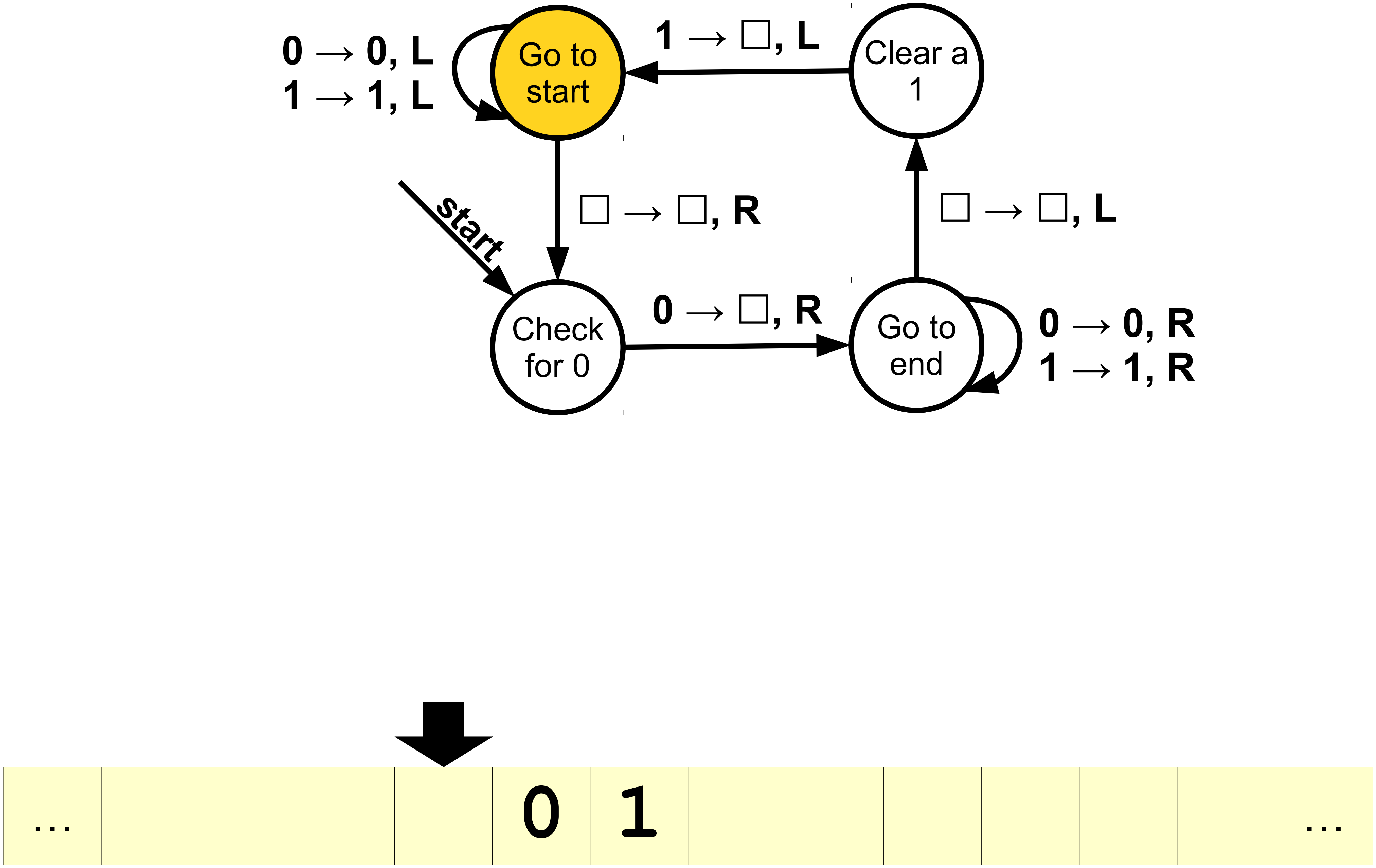

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R

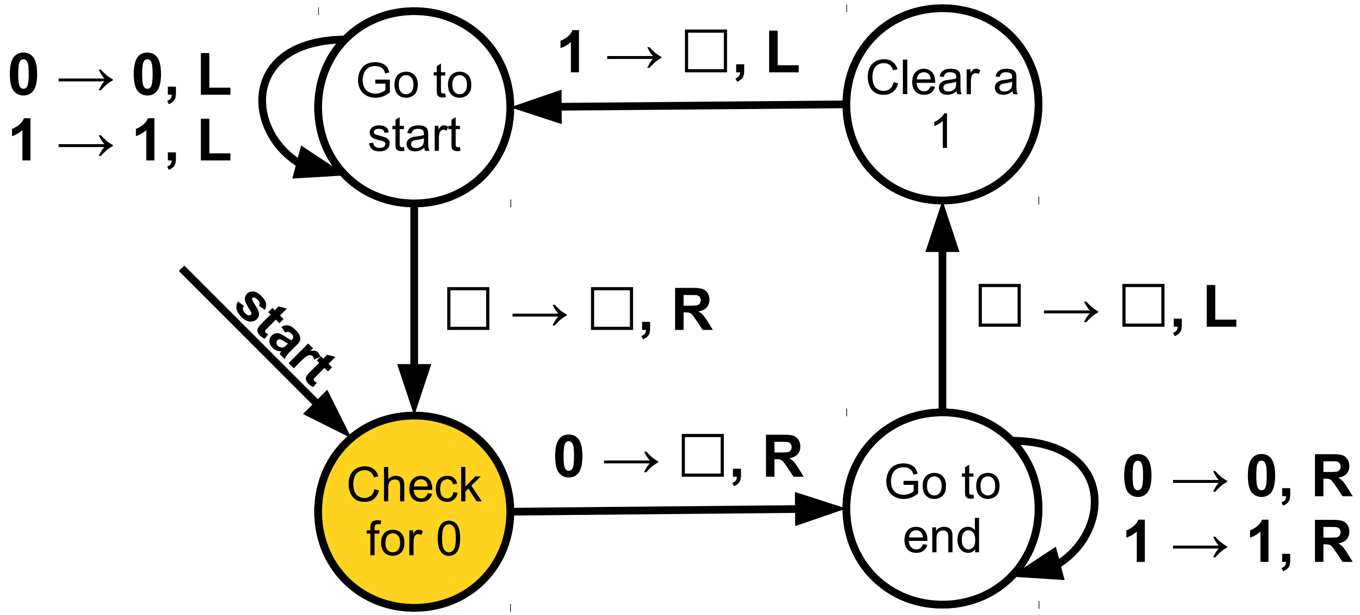


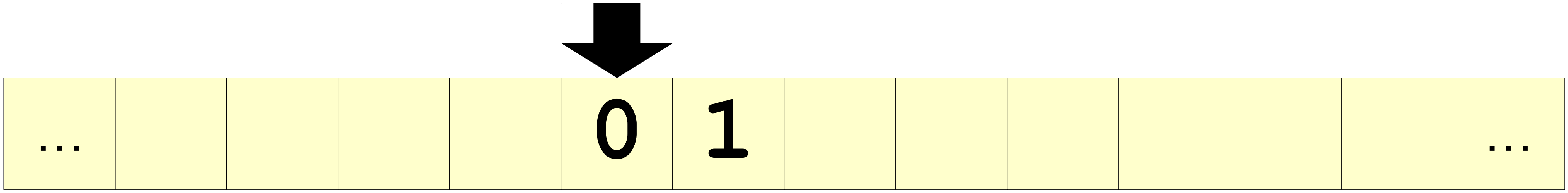
…					0	1	1						…

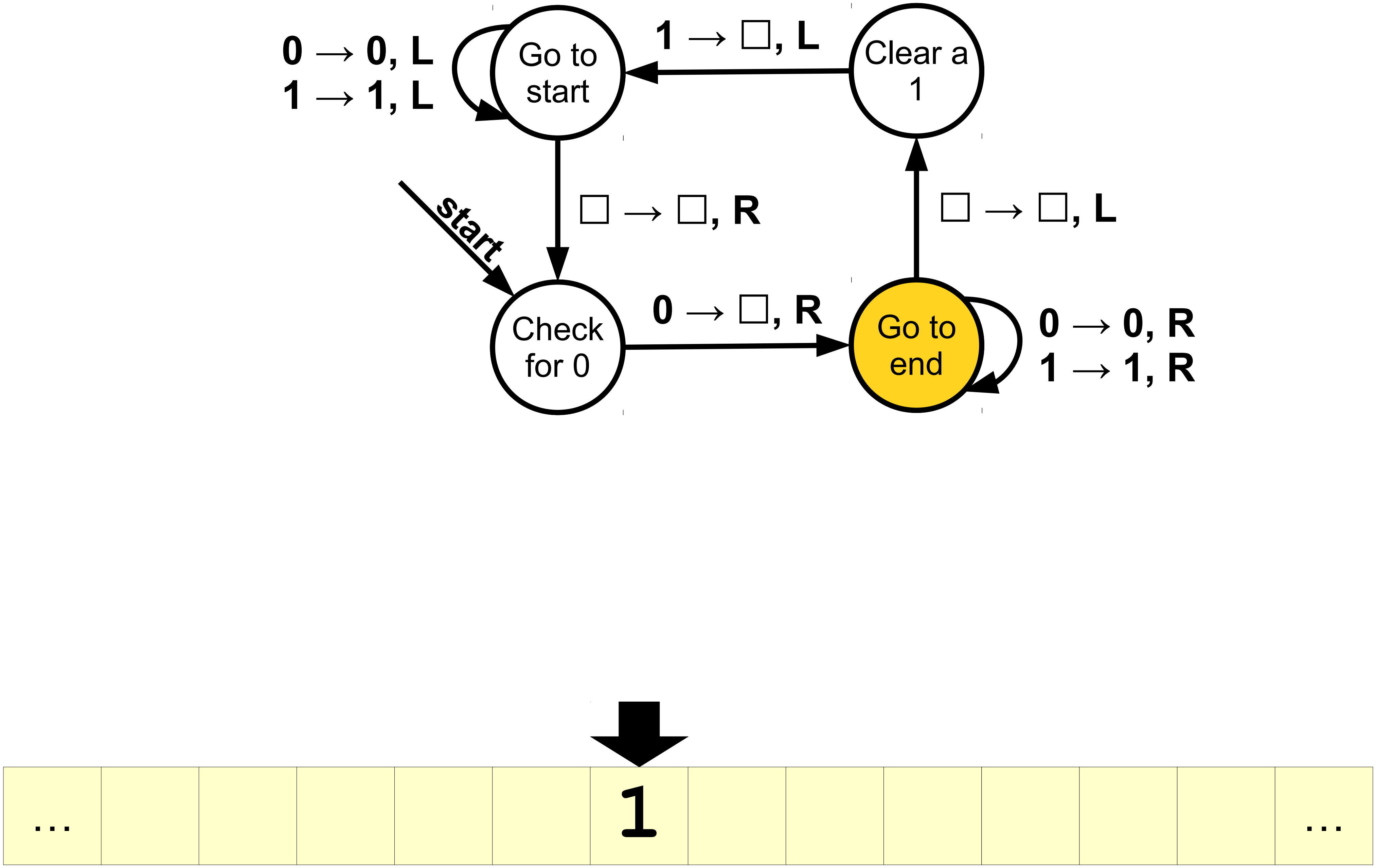

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
…
0
1
…

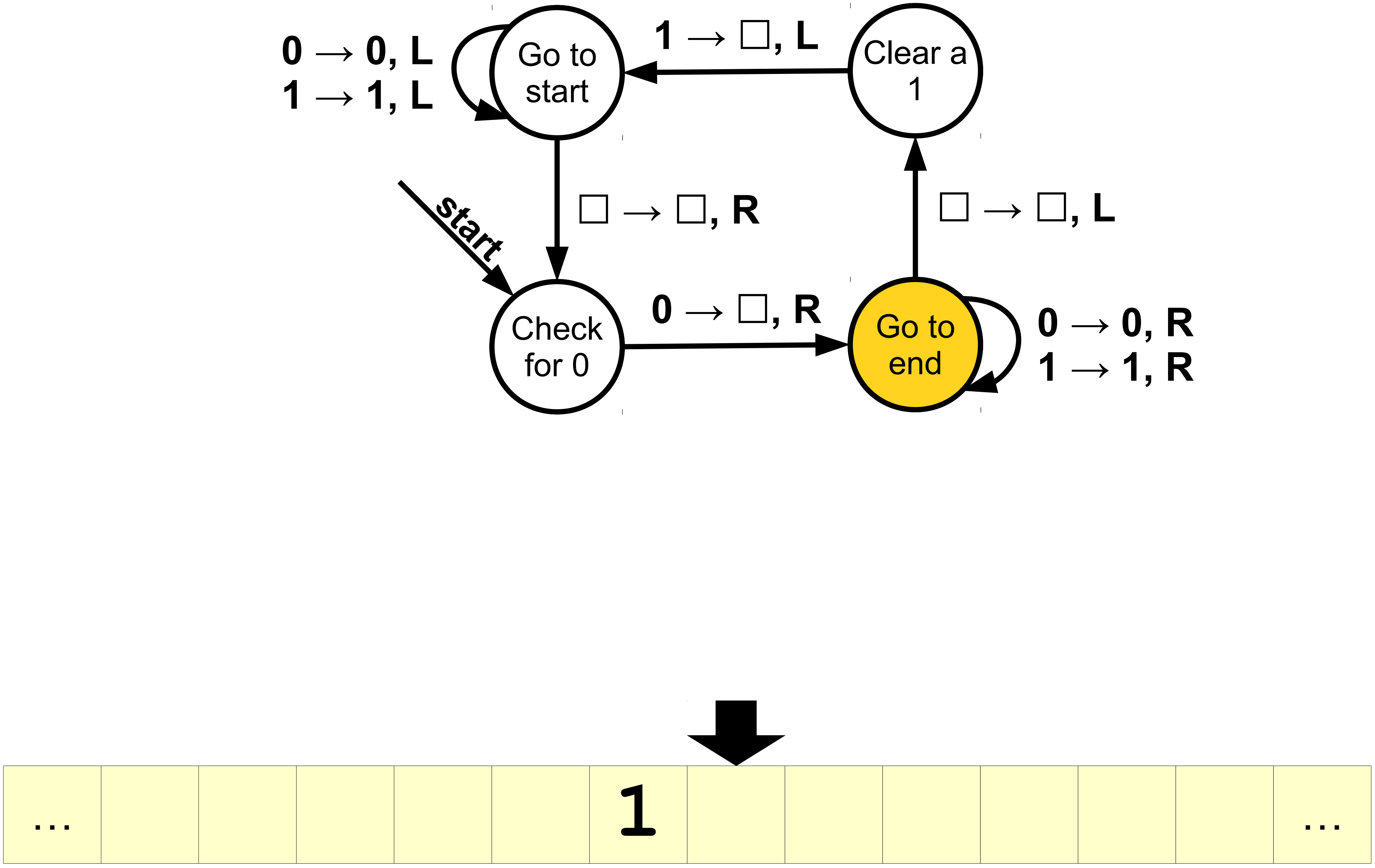

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
□ → □, R
start
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
…
0
1
…

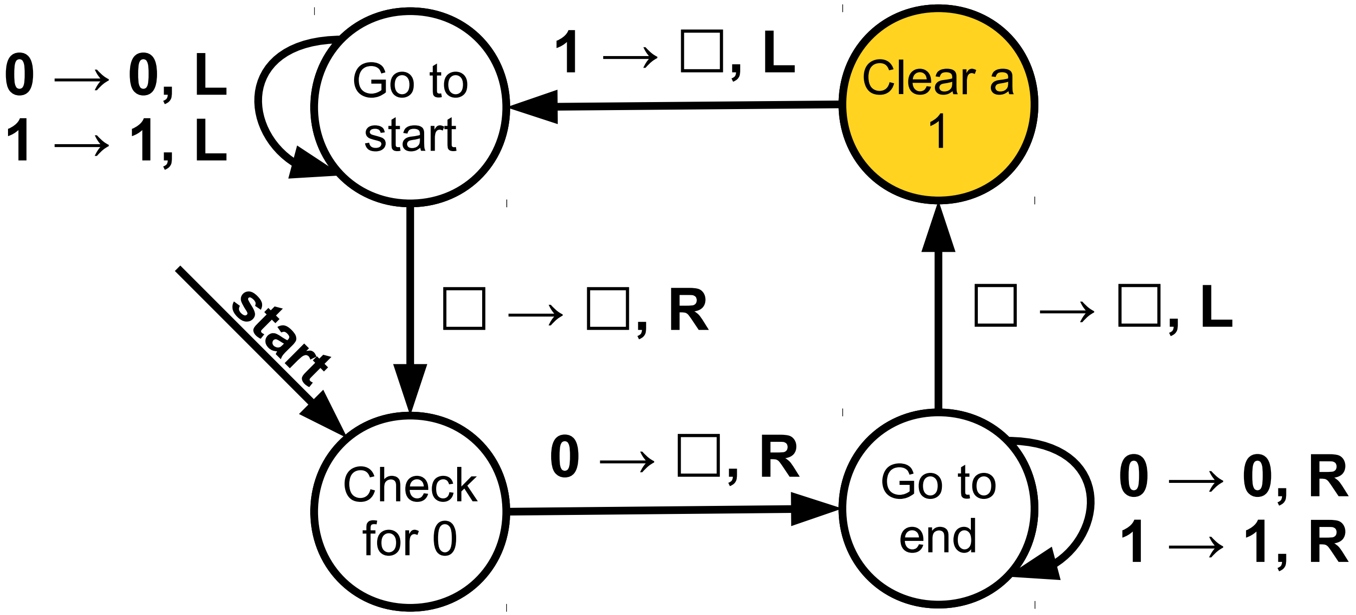

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
…
0
1
…

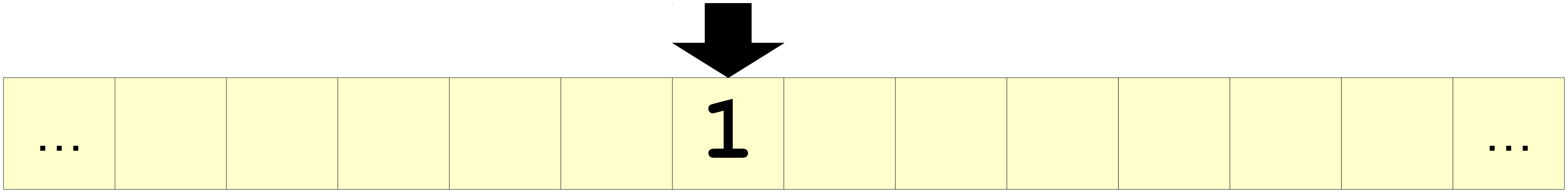

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R

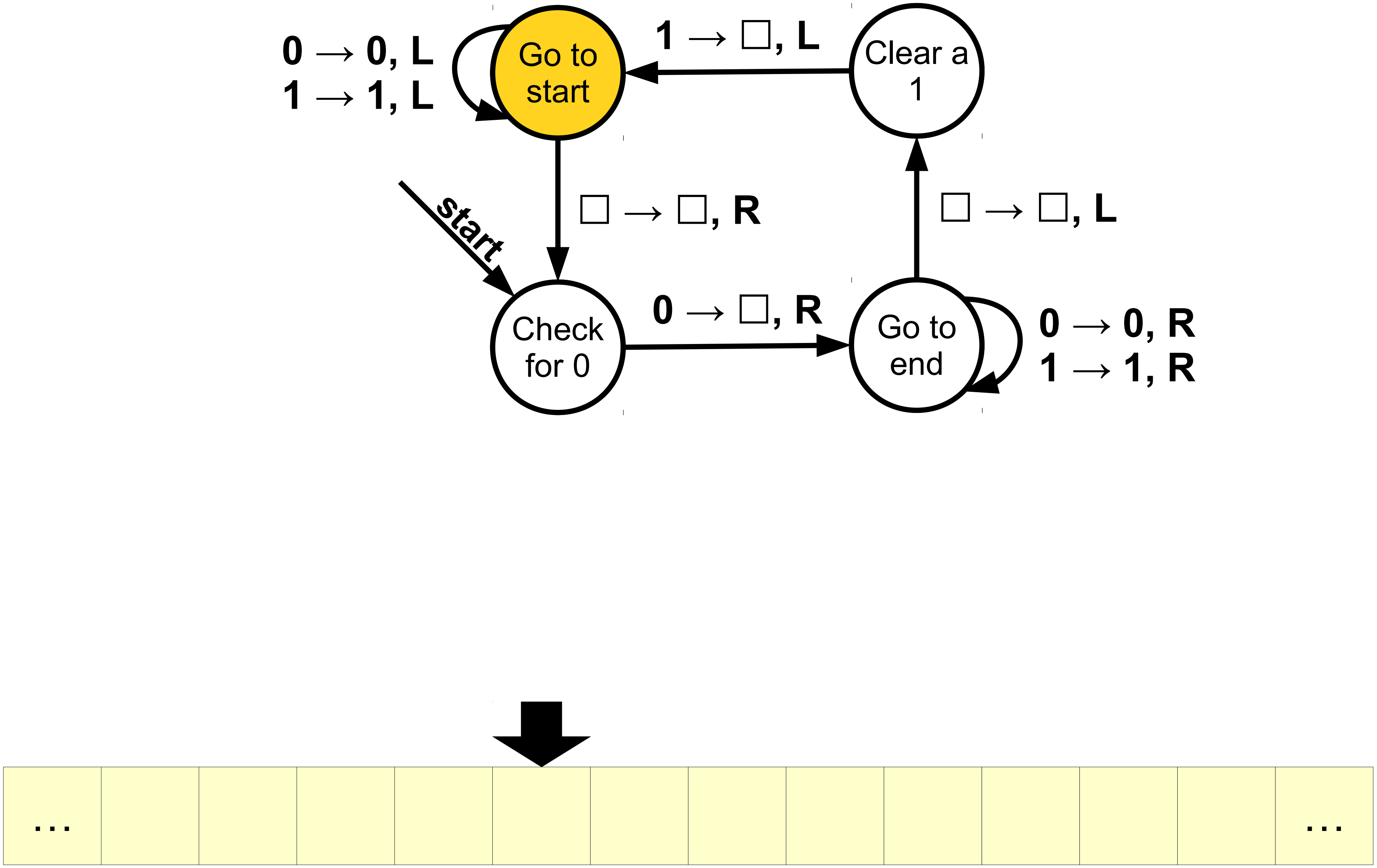

…
0
1
…

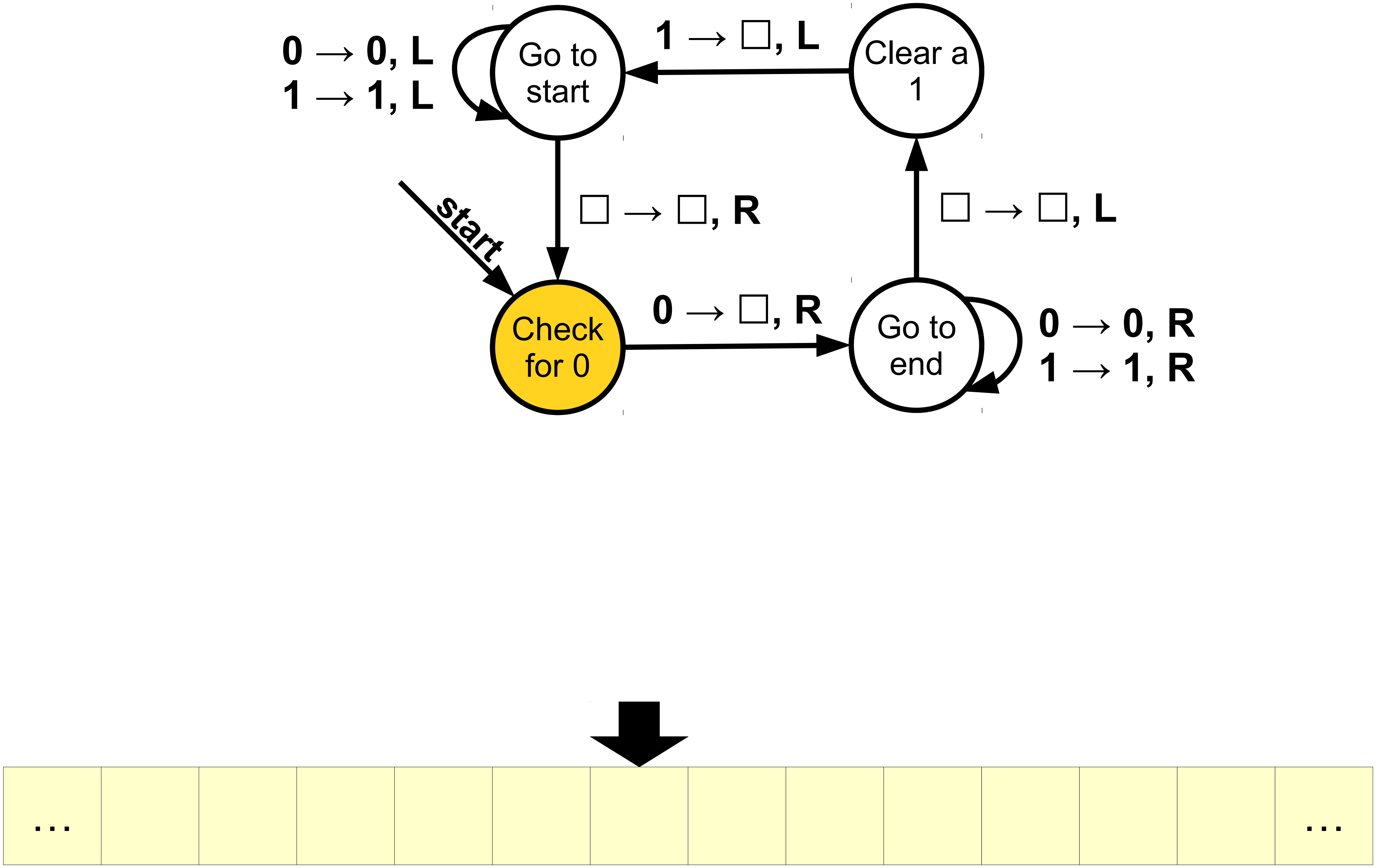

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
…
1
…

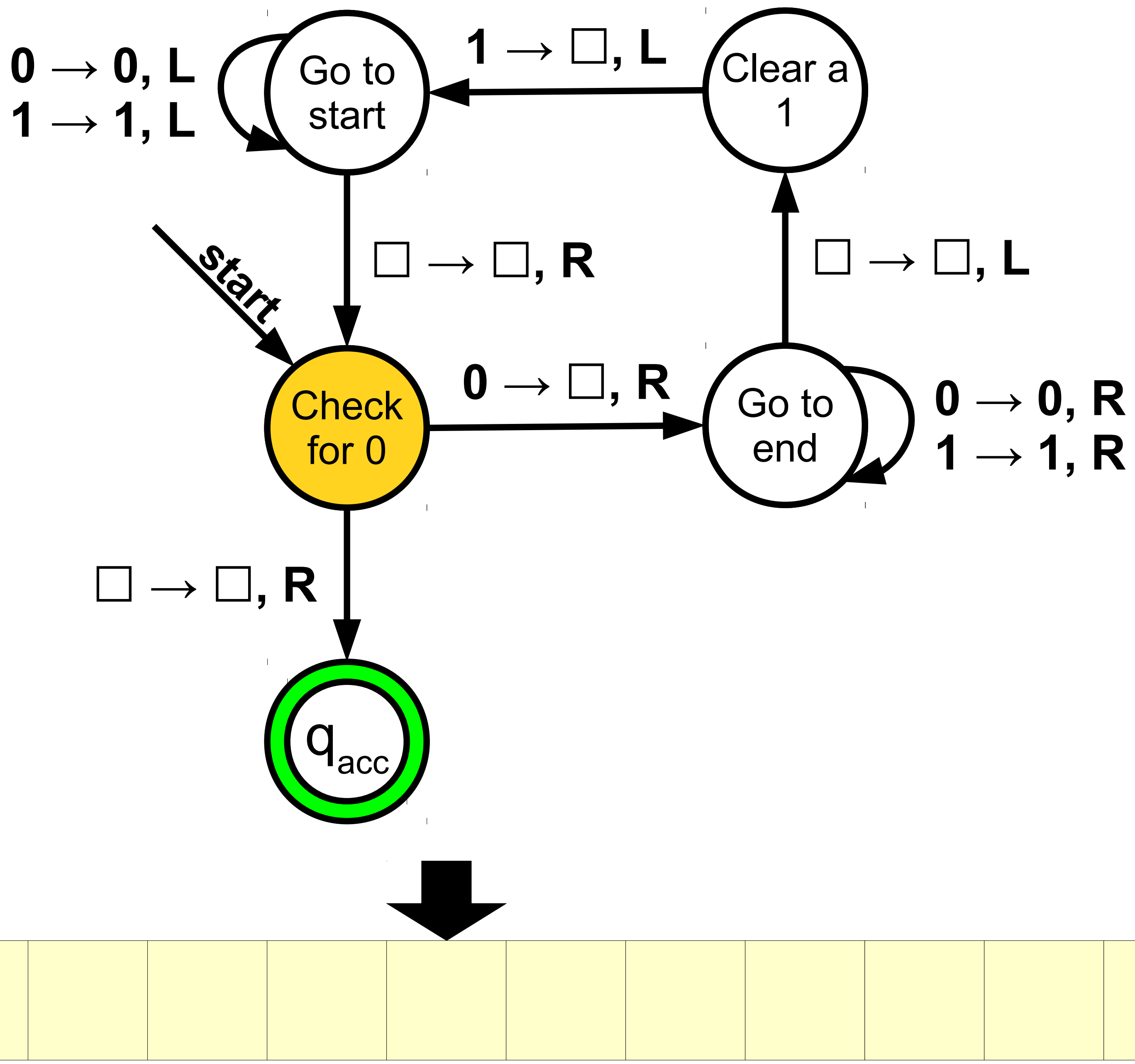

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
…
1
…

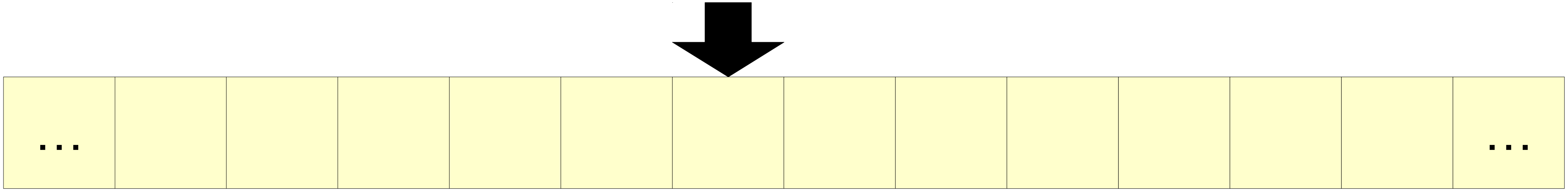

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R

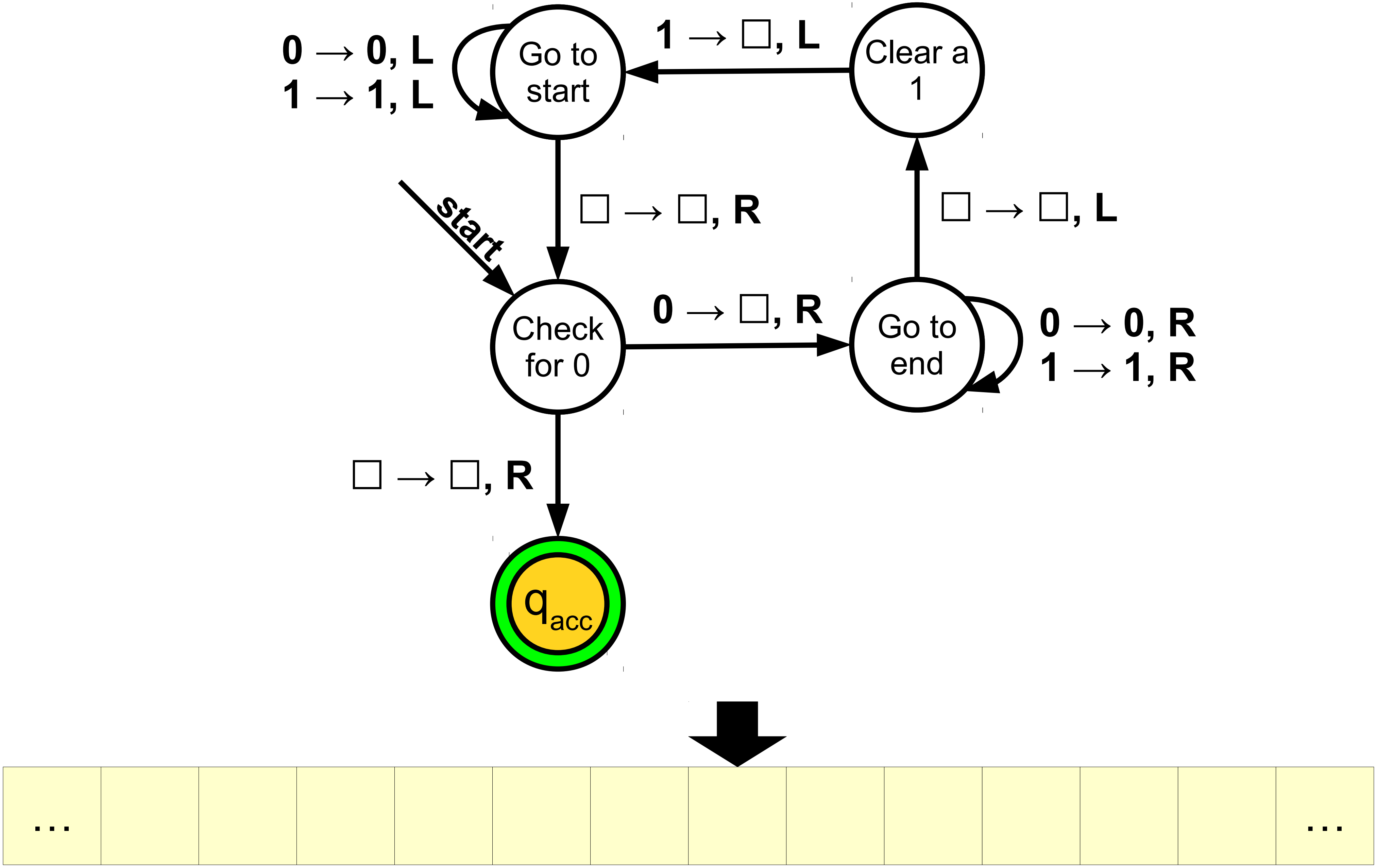

…
1
…

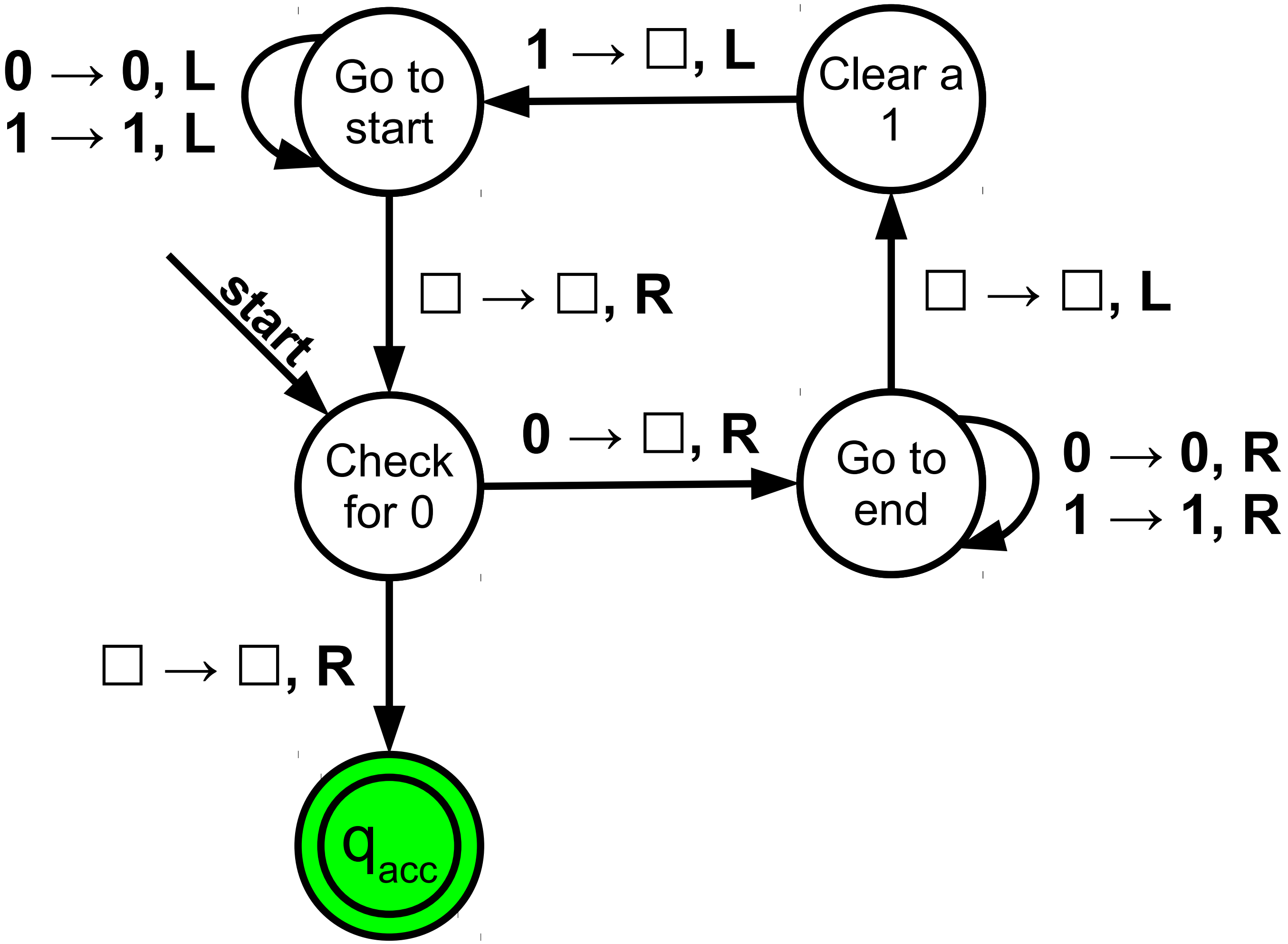

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
…
…

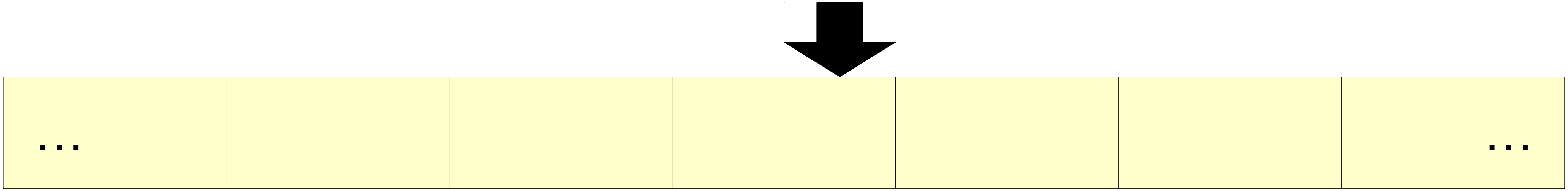

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
…
…

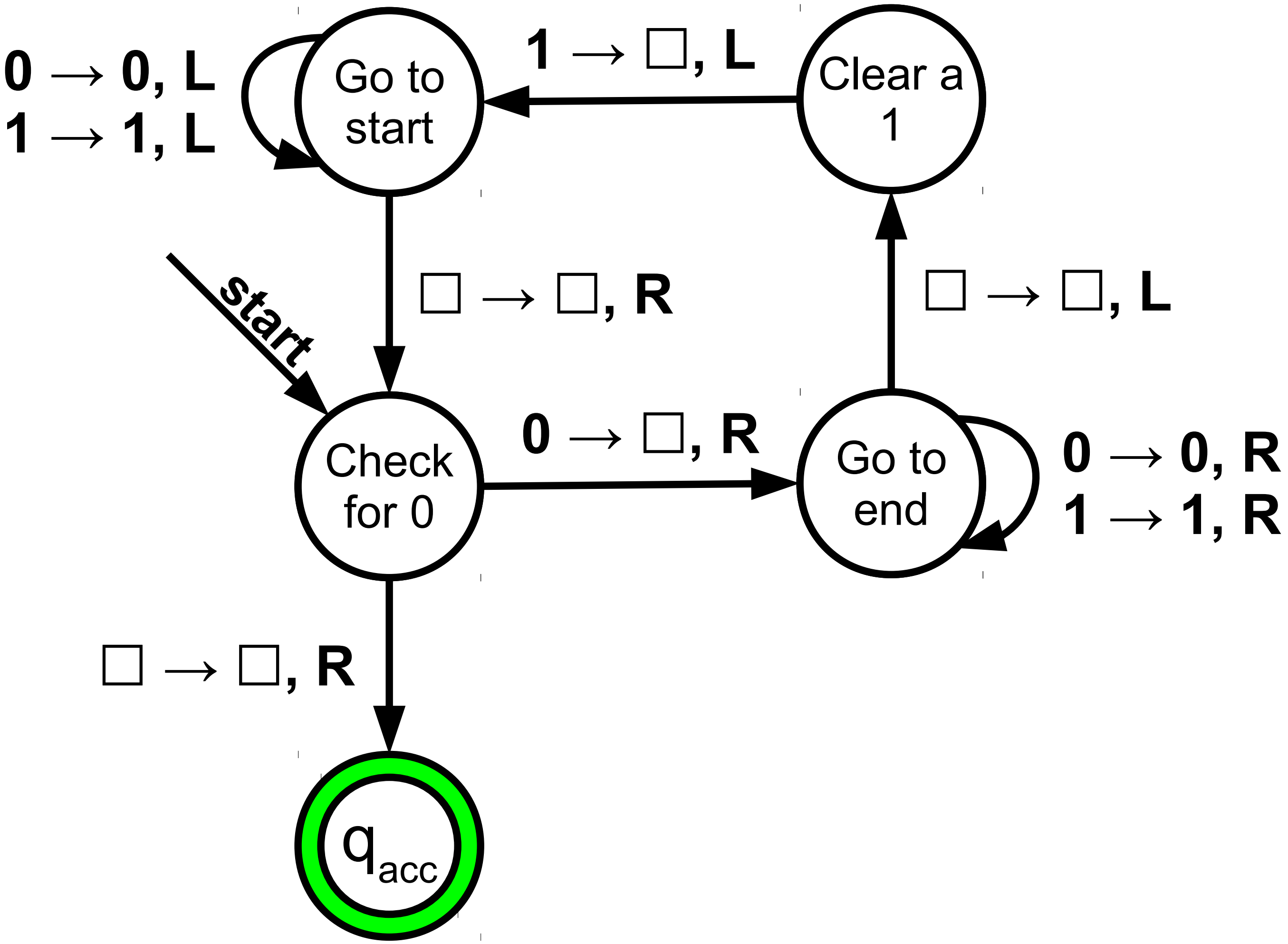

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}

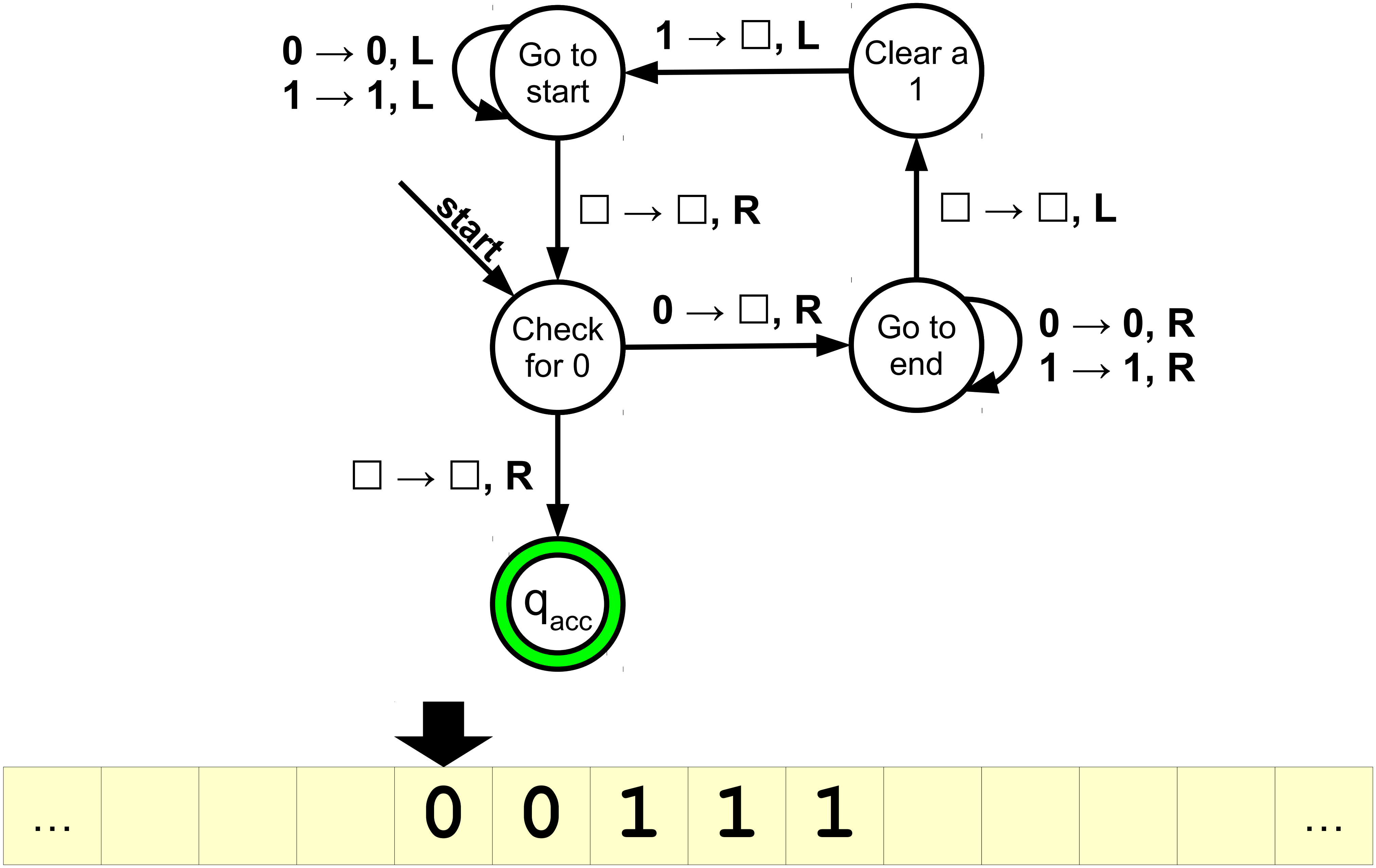

…
…

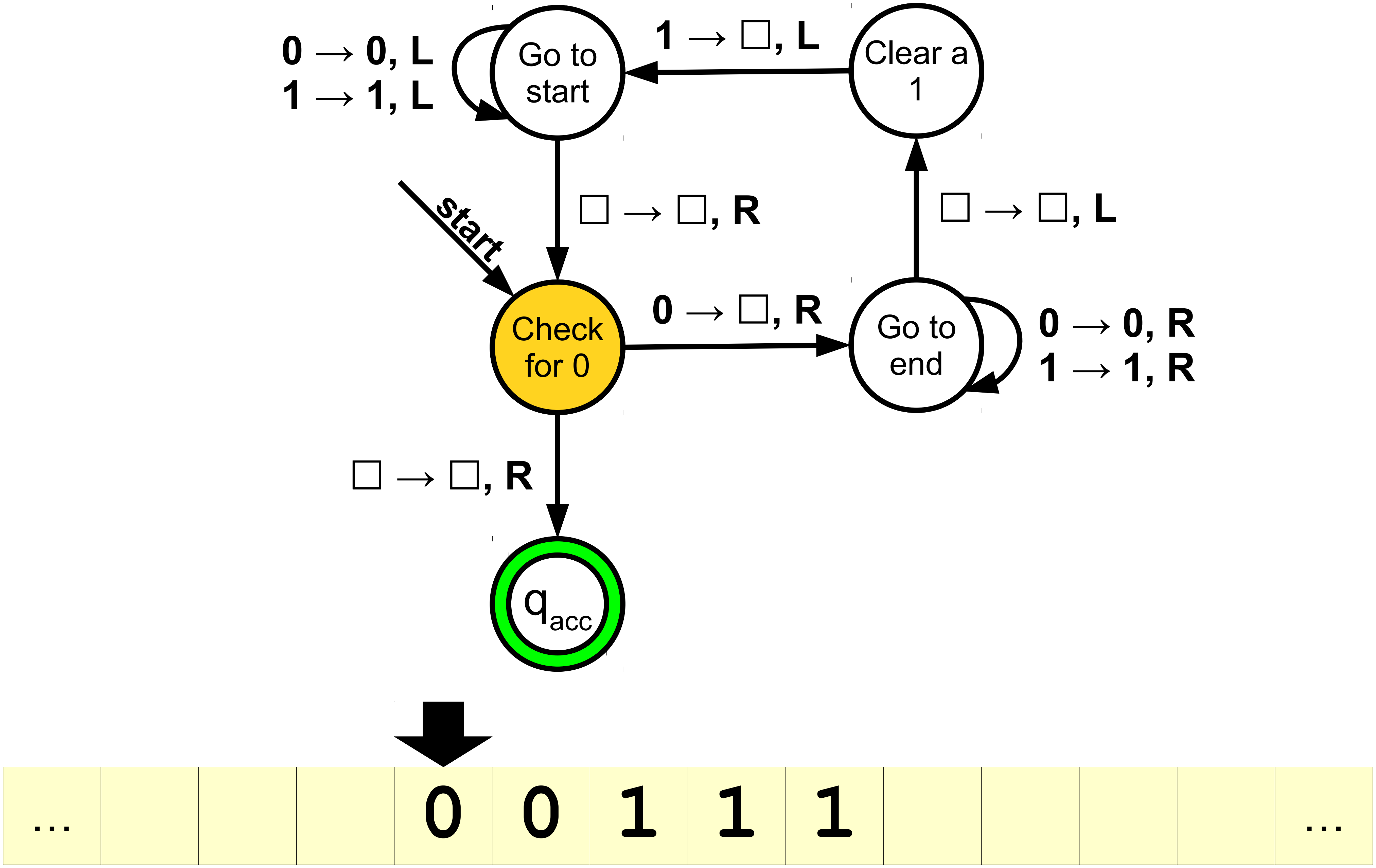

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
…

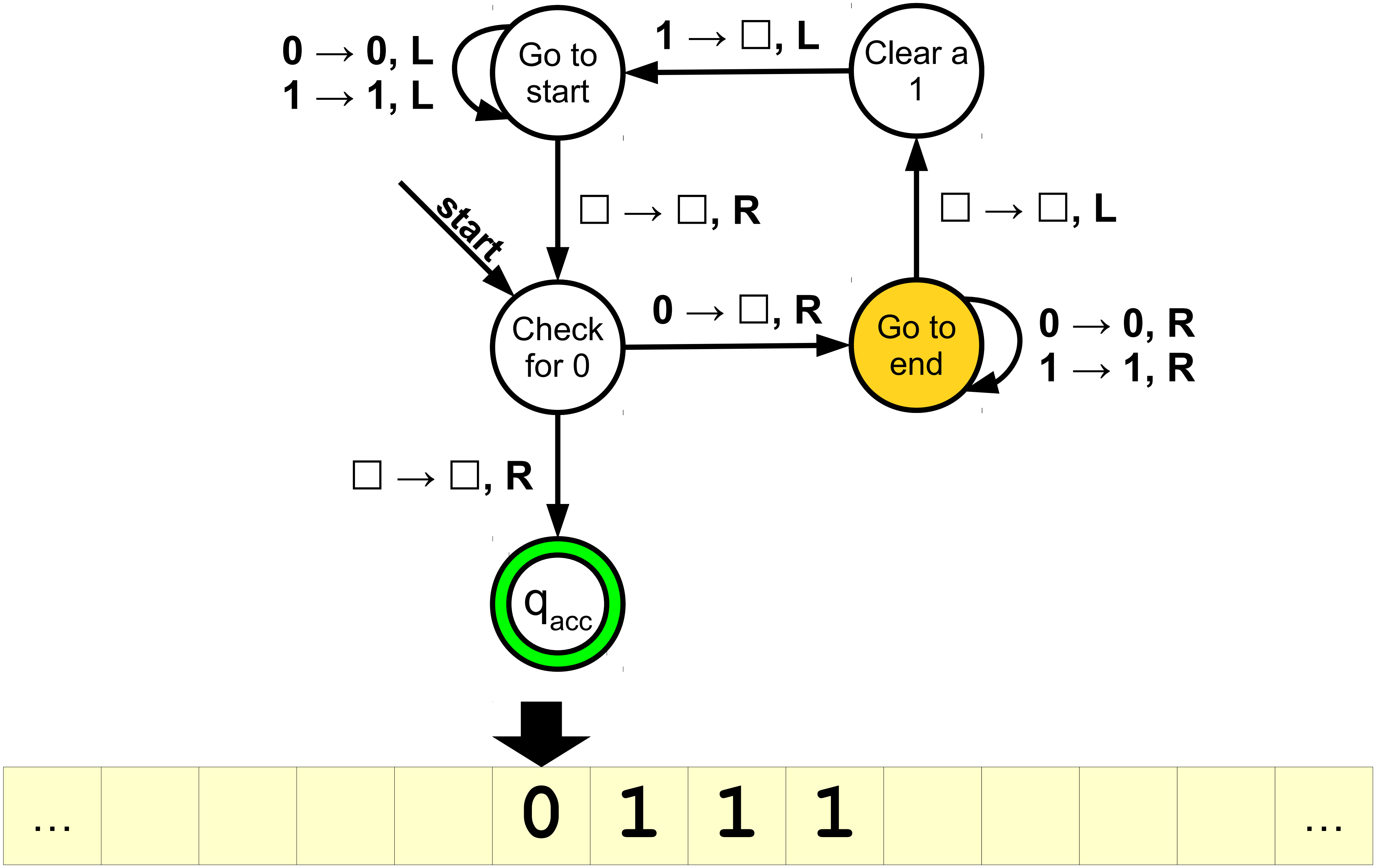

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}

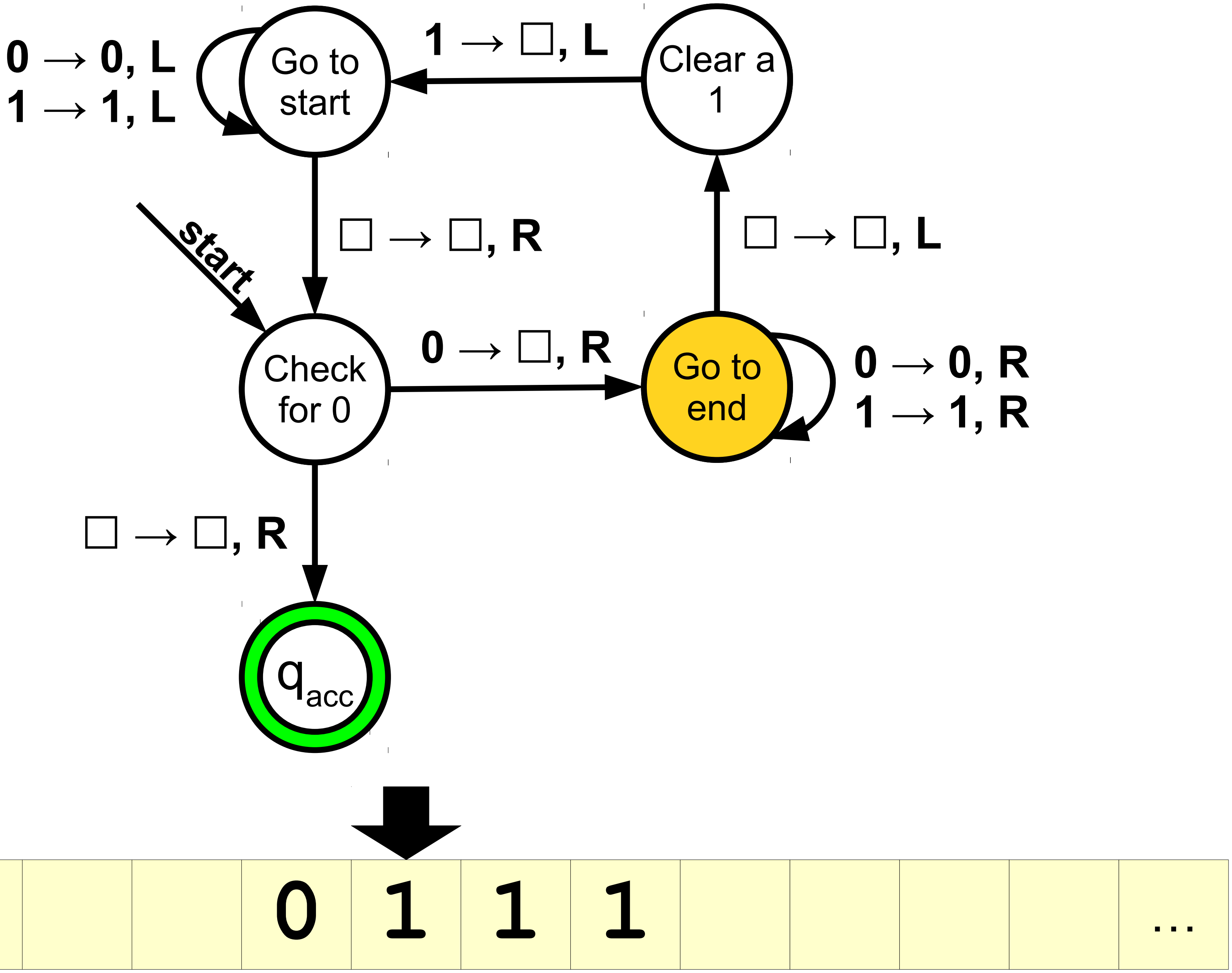

…
…

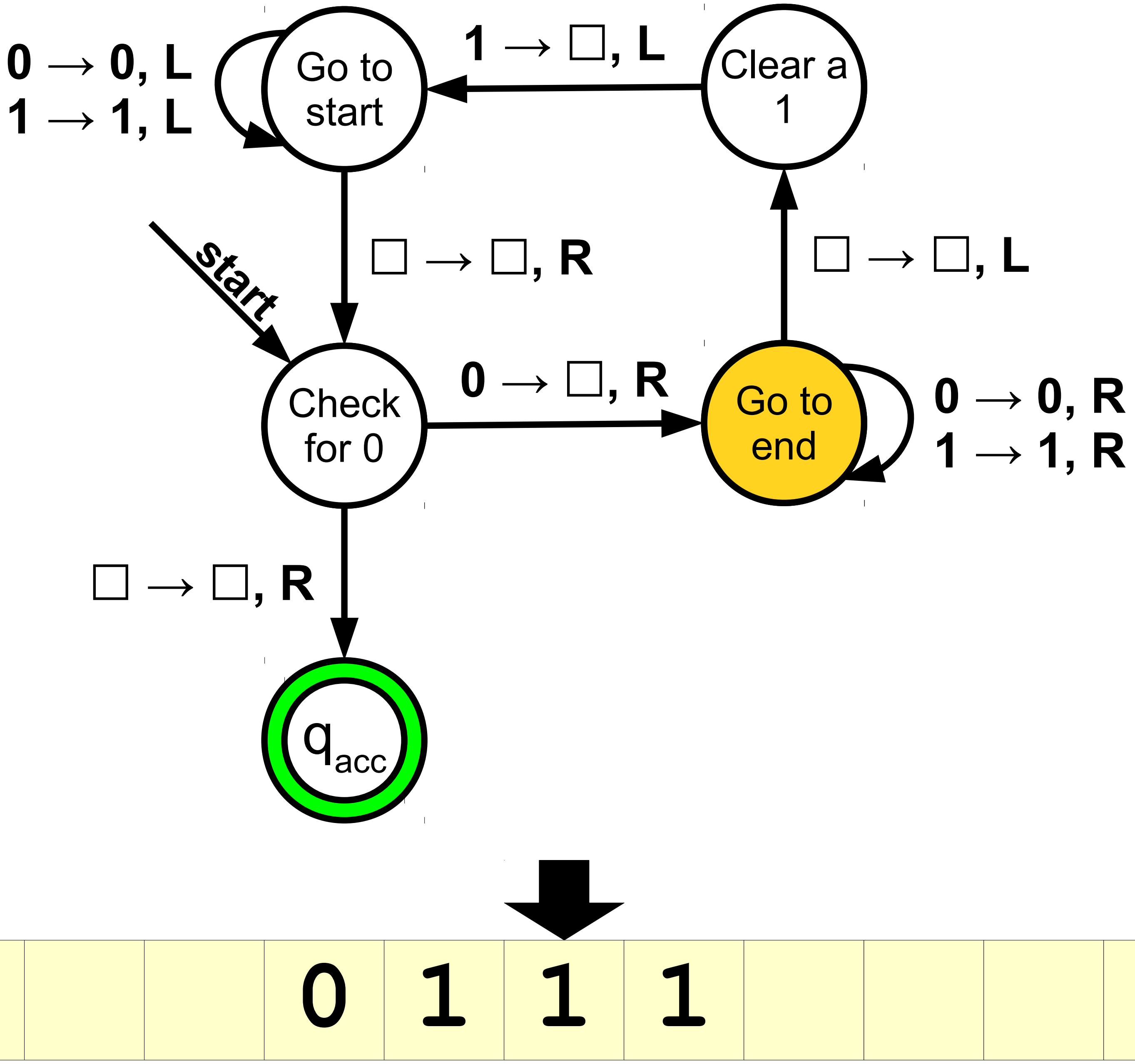

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}


0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
□ → □, R
□ → □, L
start
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}
…
0
0
1
1
1
…

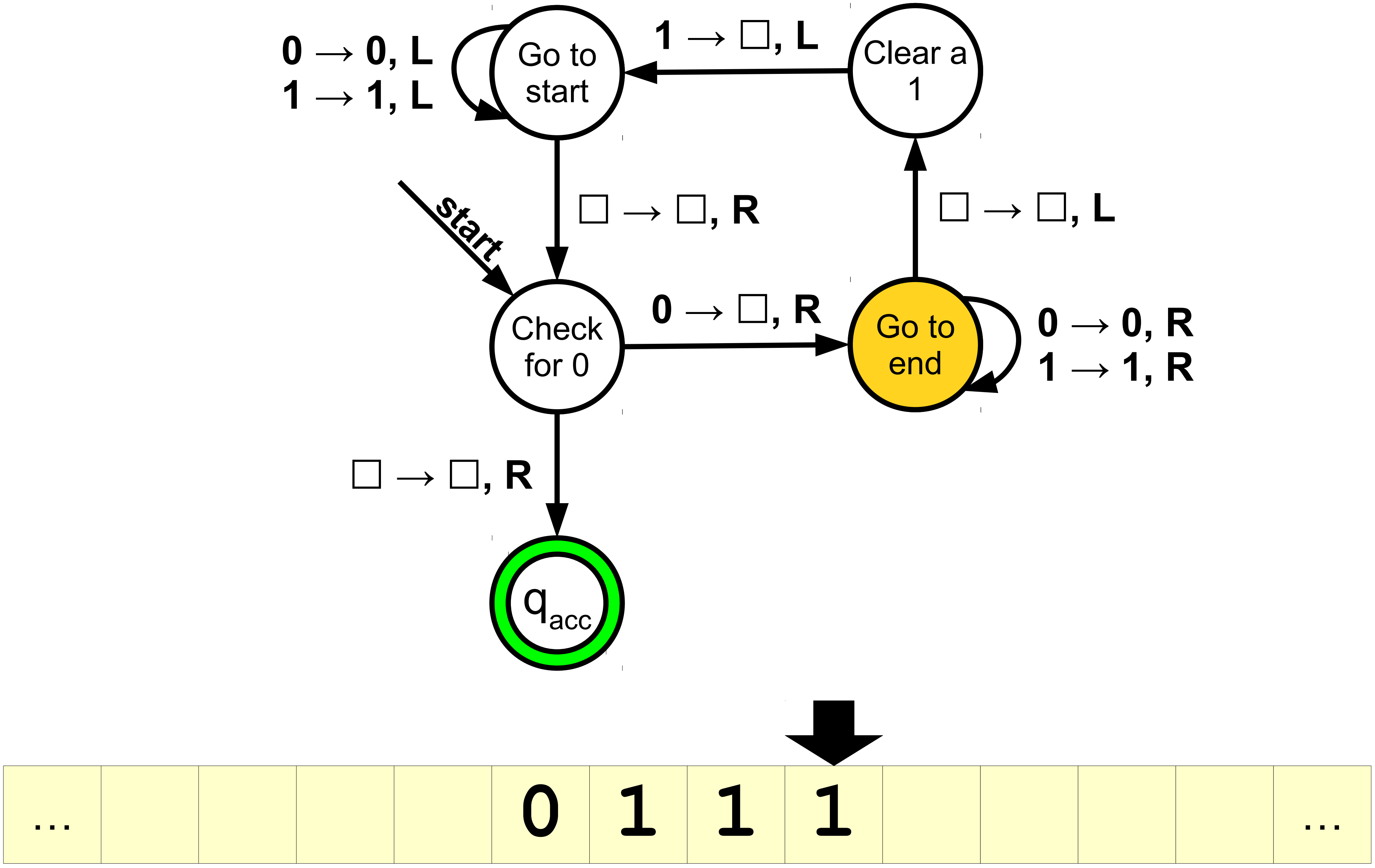

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
□ → □, R
start
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}
…
0
0
1
1
1
…

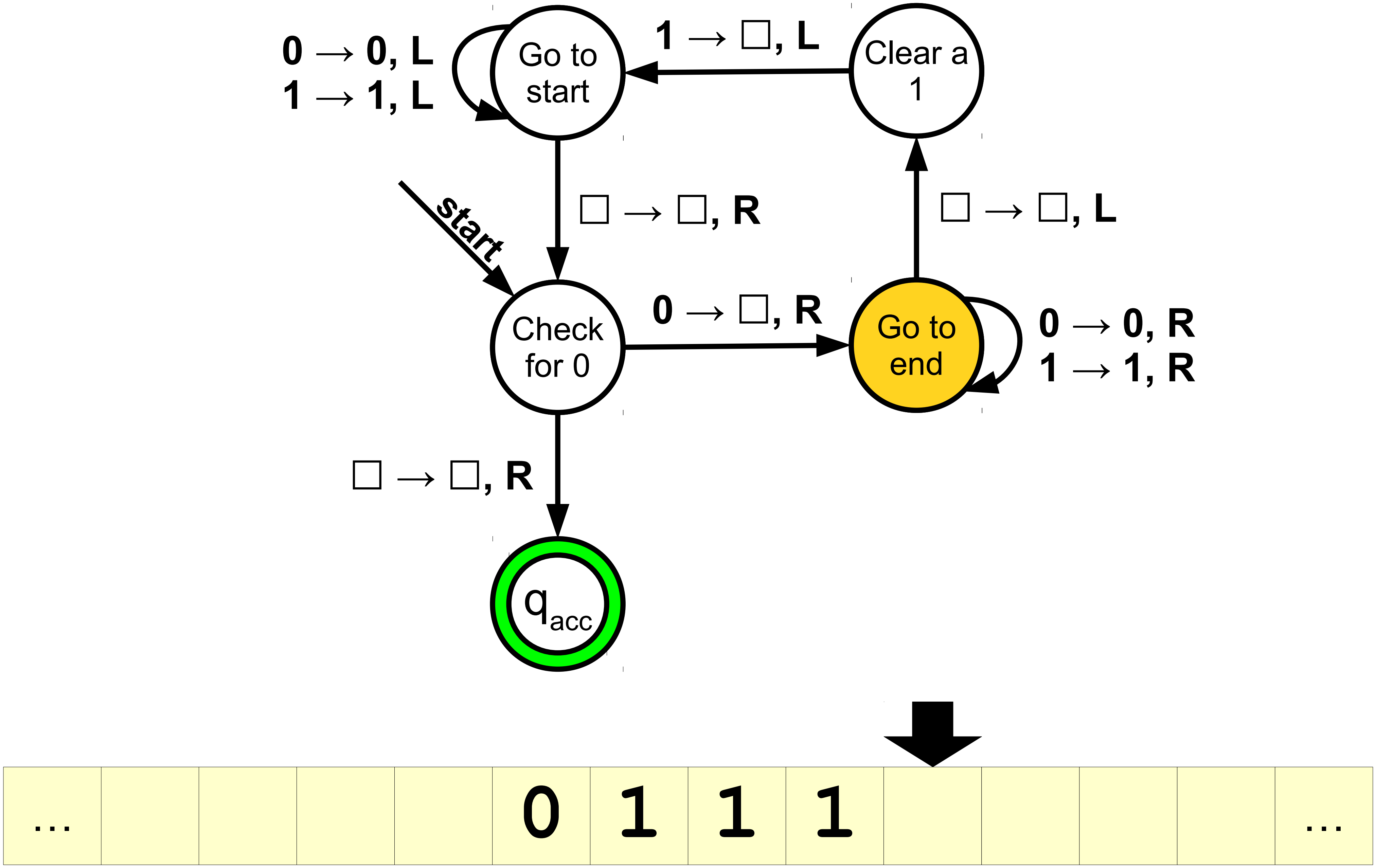

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
0
1
1
1
…

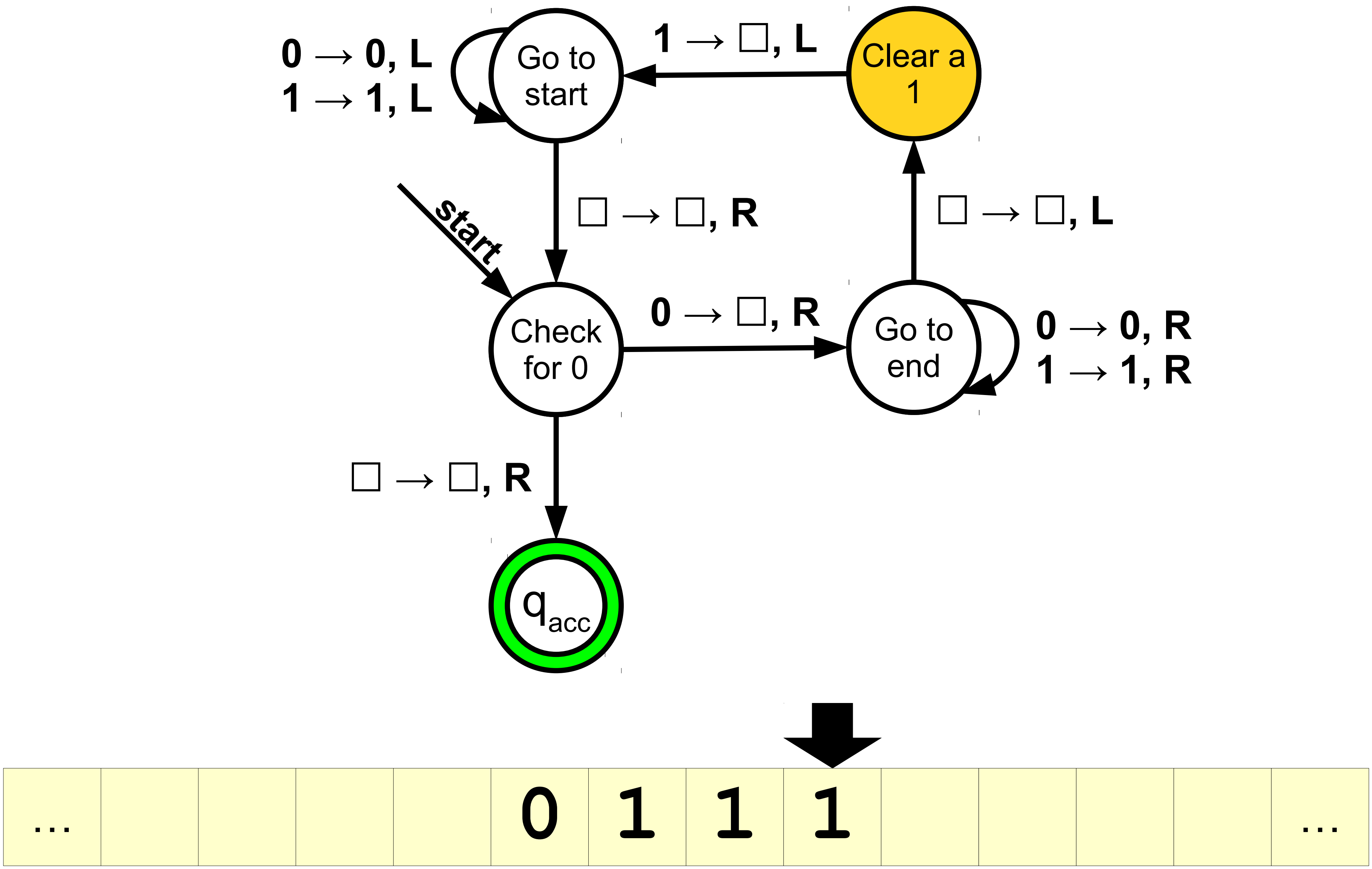

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
0
1
1
1
…

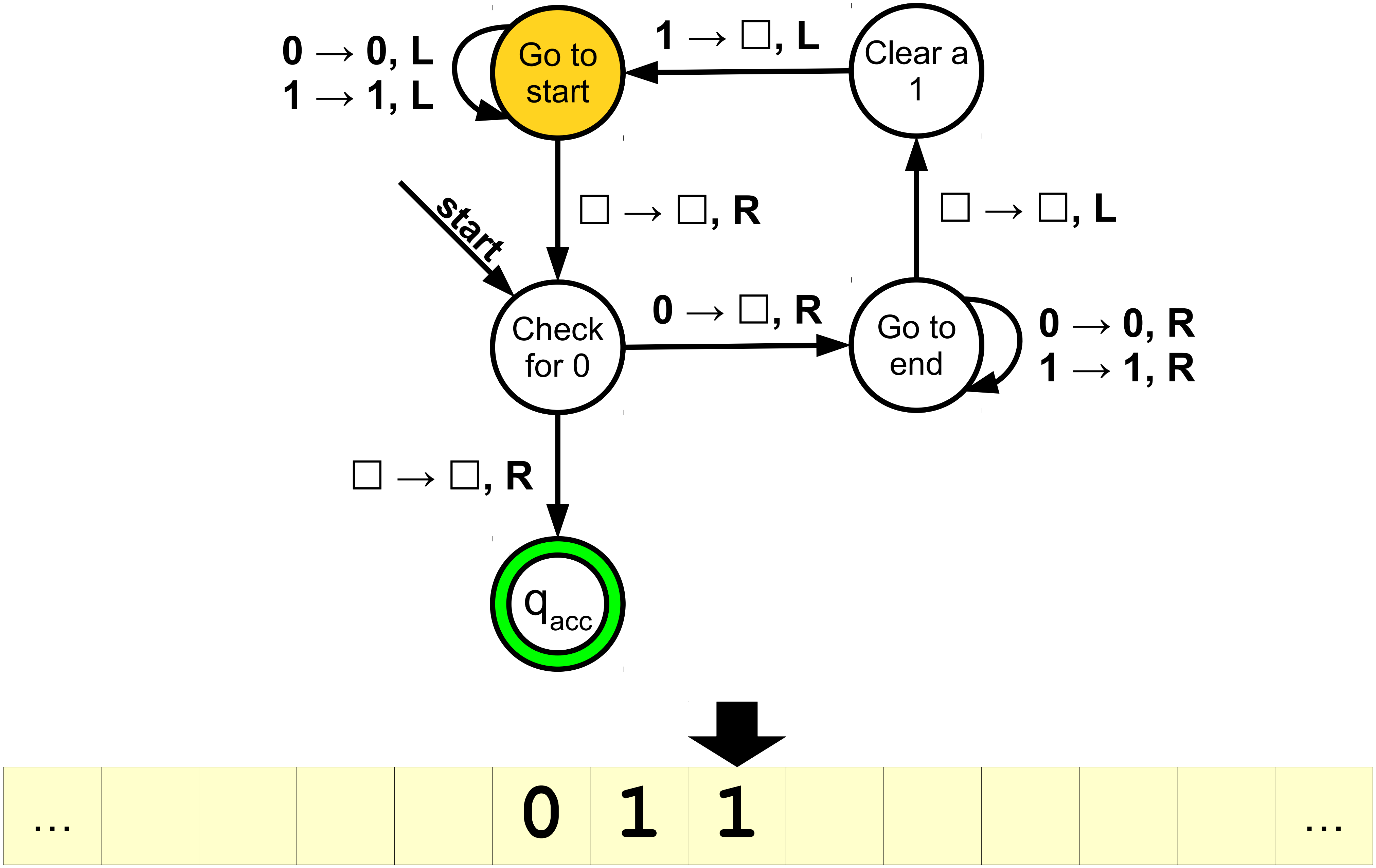

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
□ → □, R
start
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}

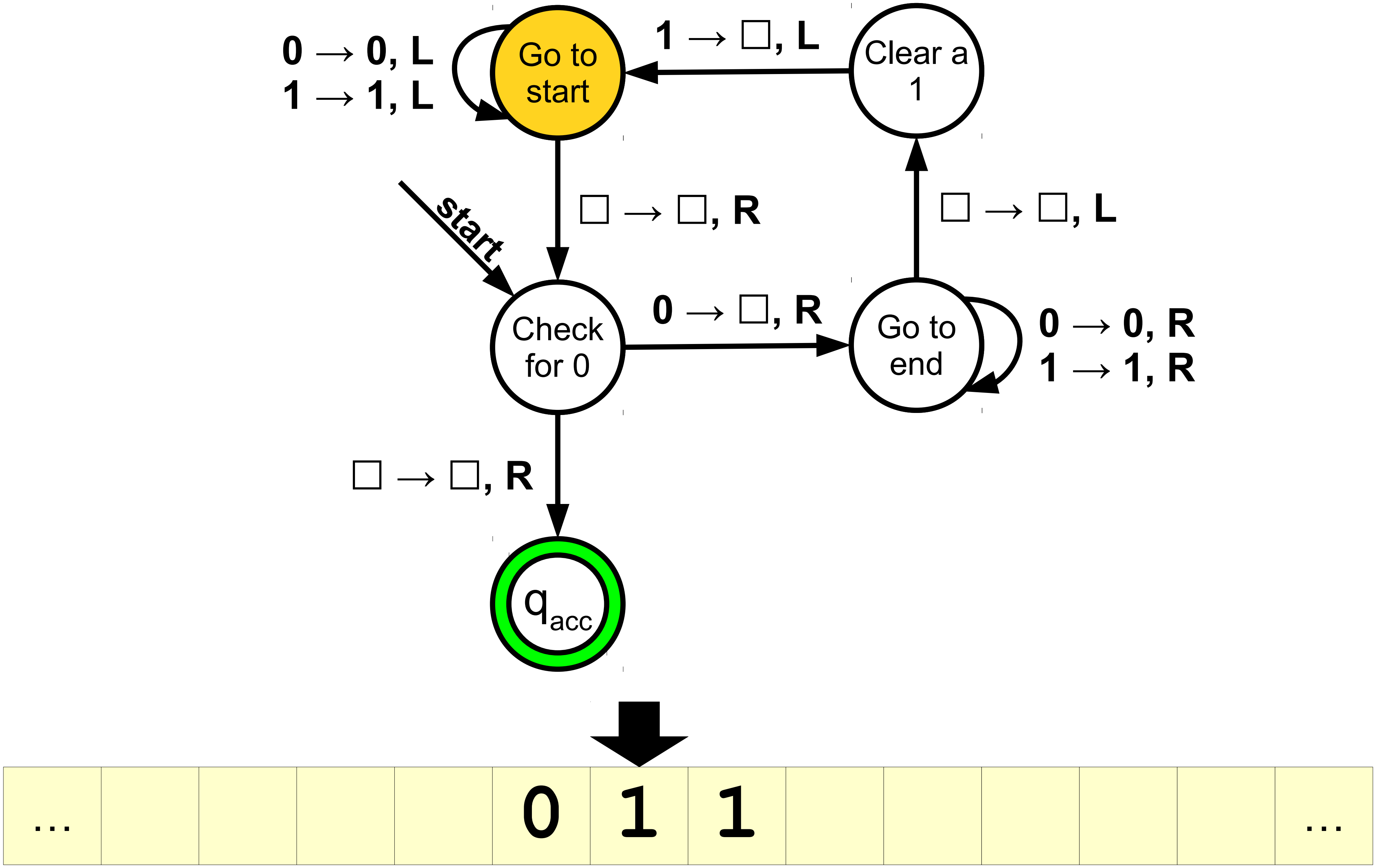
…					0	1	1	1					…

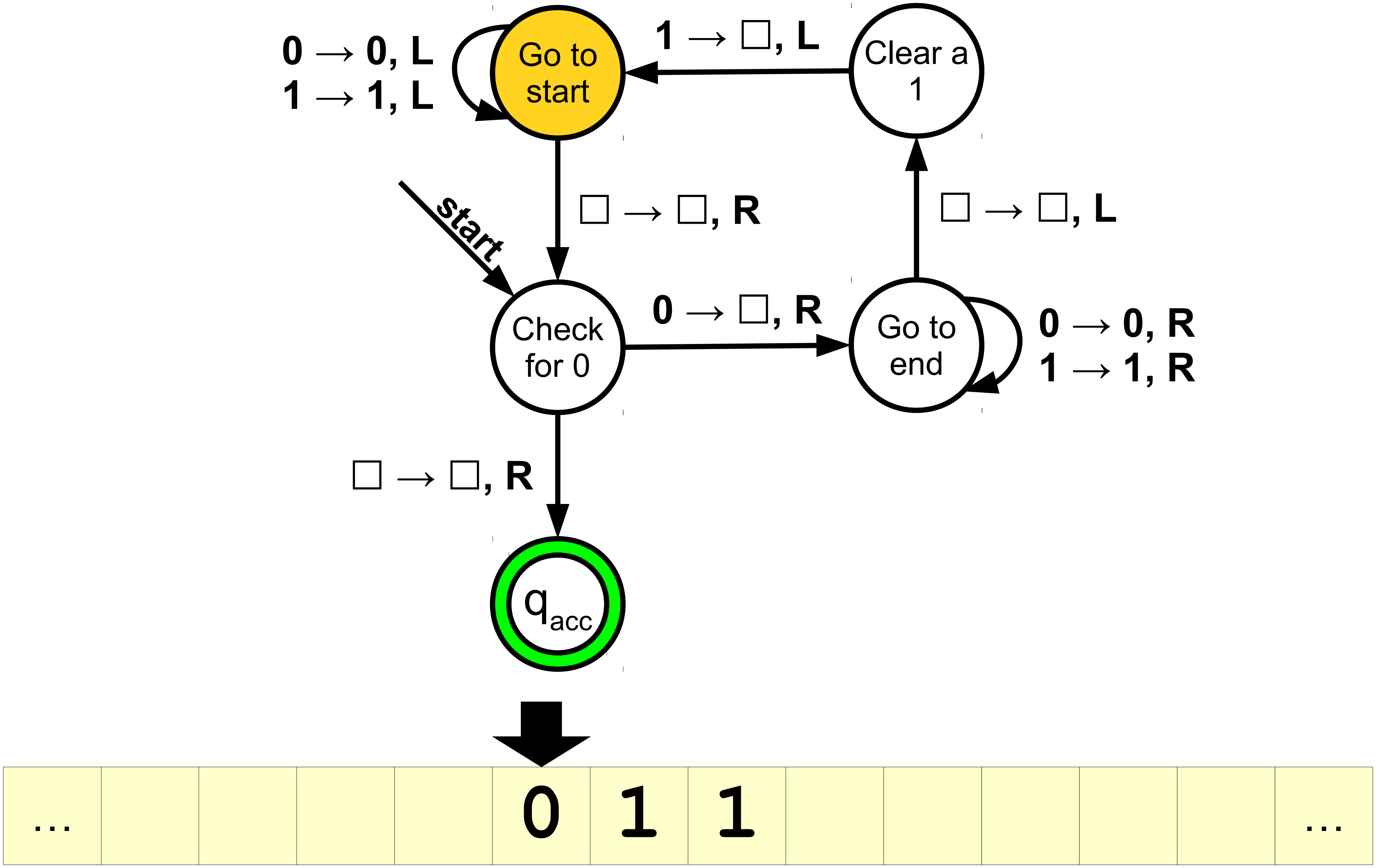

Go to start
Clear a 1
Check for 0
Go to end
q_{acc}
start
0 → 0, L
1 → 1, L
1 → □, L
□ → □, R
□ → □, L
0 → □, R
0 → 0, R
1 → 1, R
□ → □, R
…
0
1
1
1
…

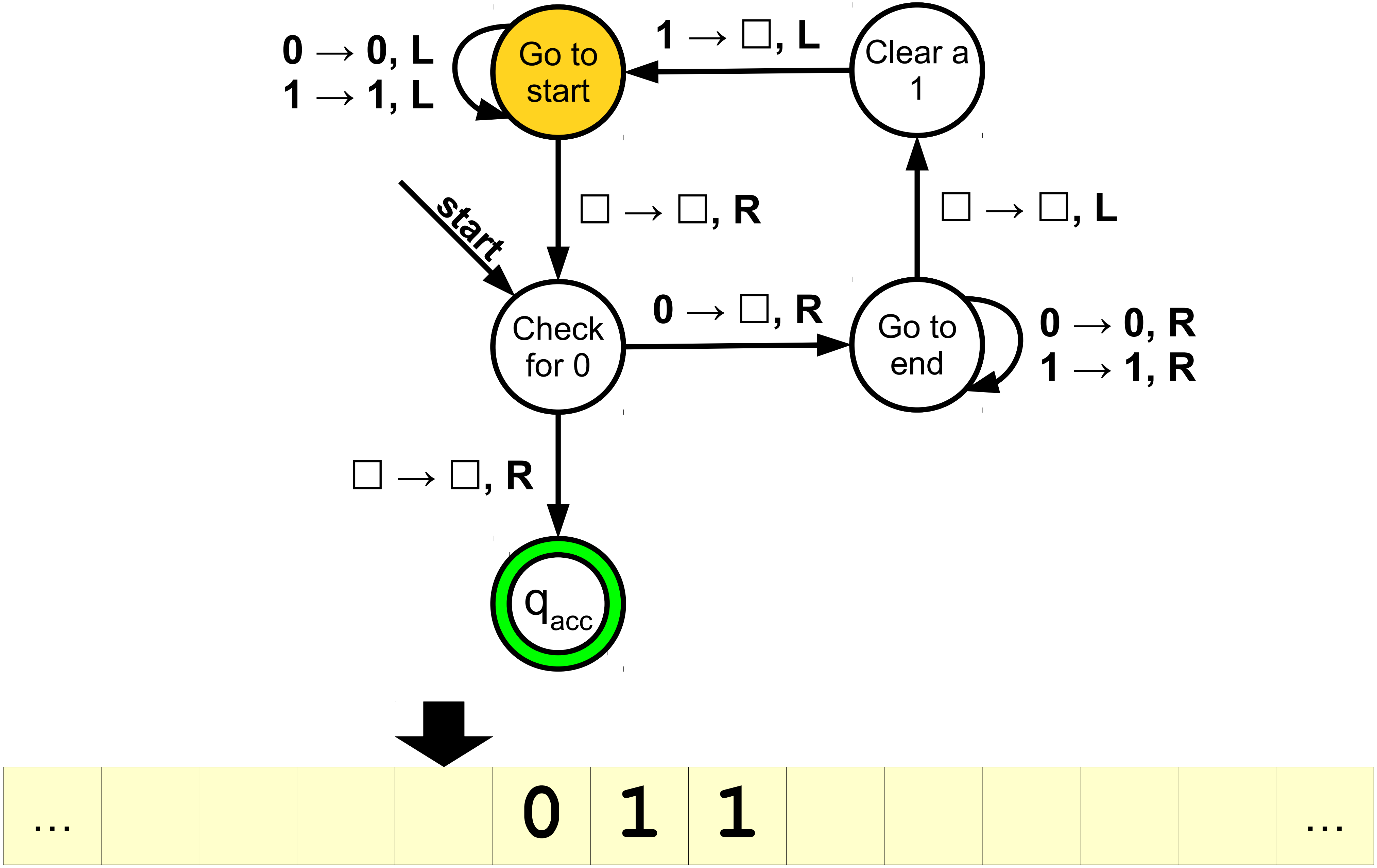

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}
…
0
1
1
1
…

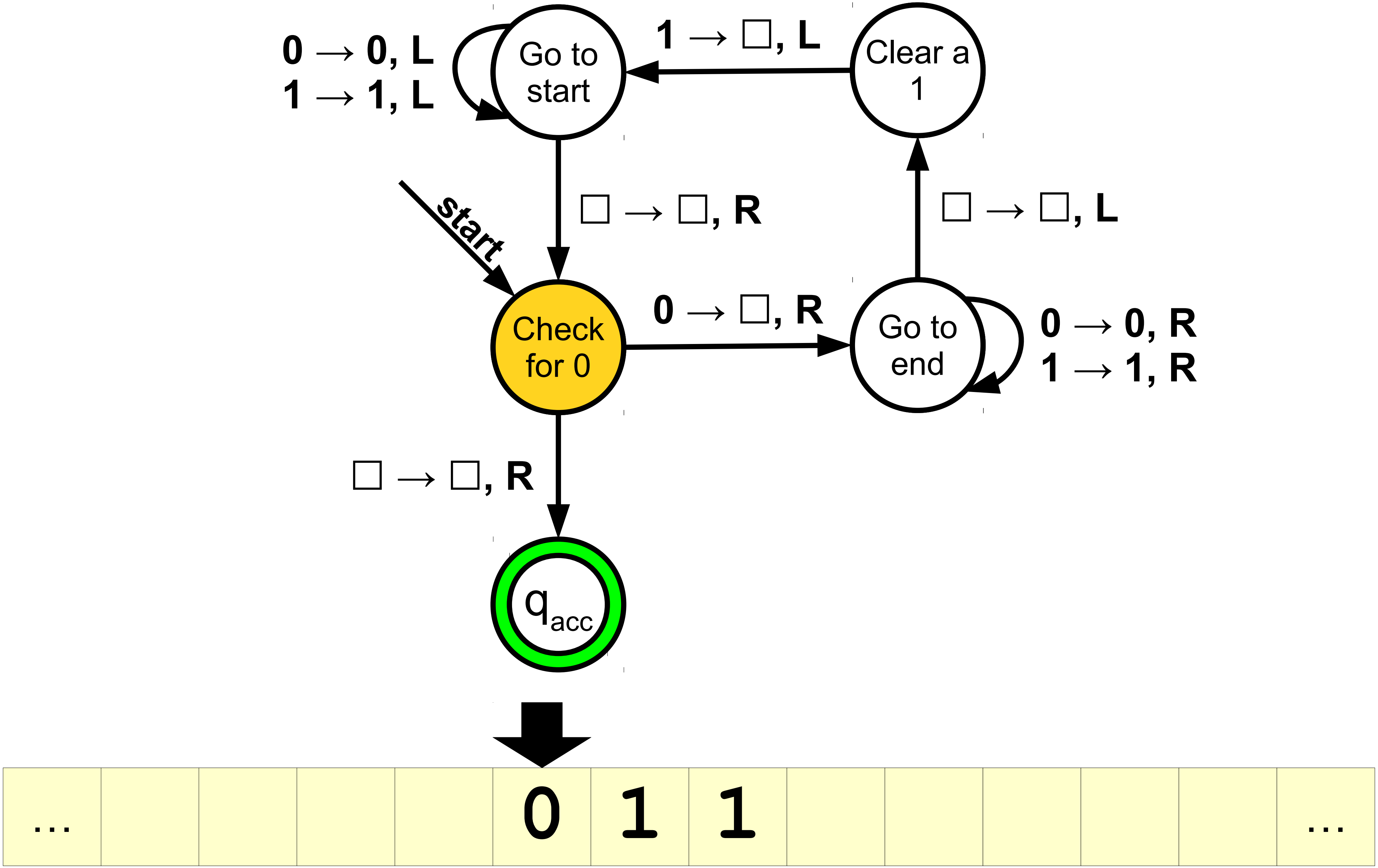

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
0
1
1
1
…

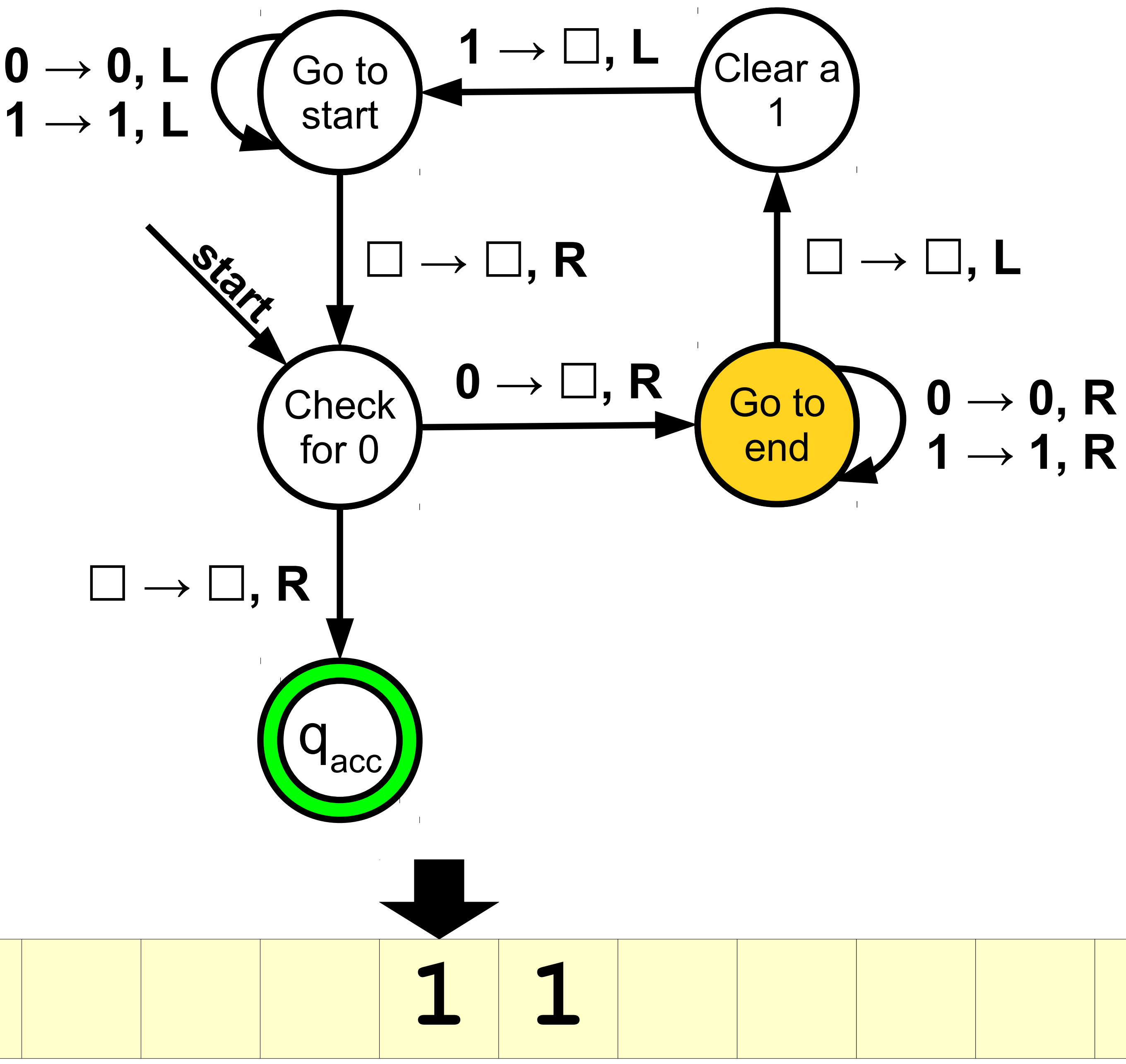

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
0
1
1
…


0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}
…
0
1
1
…

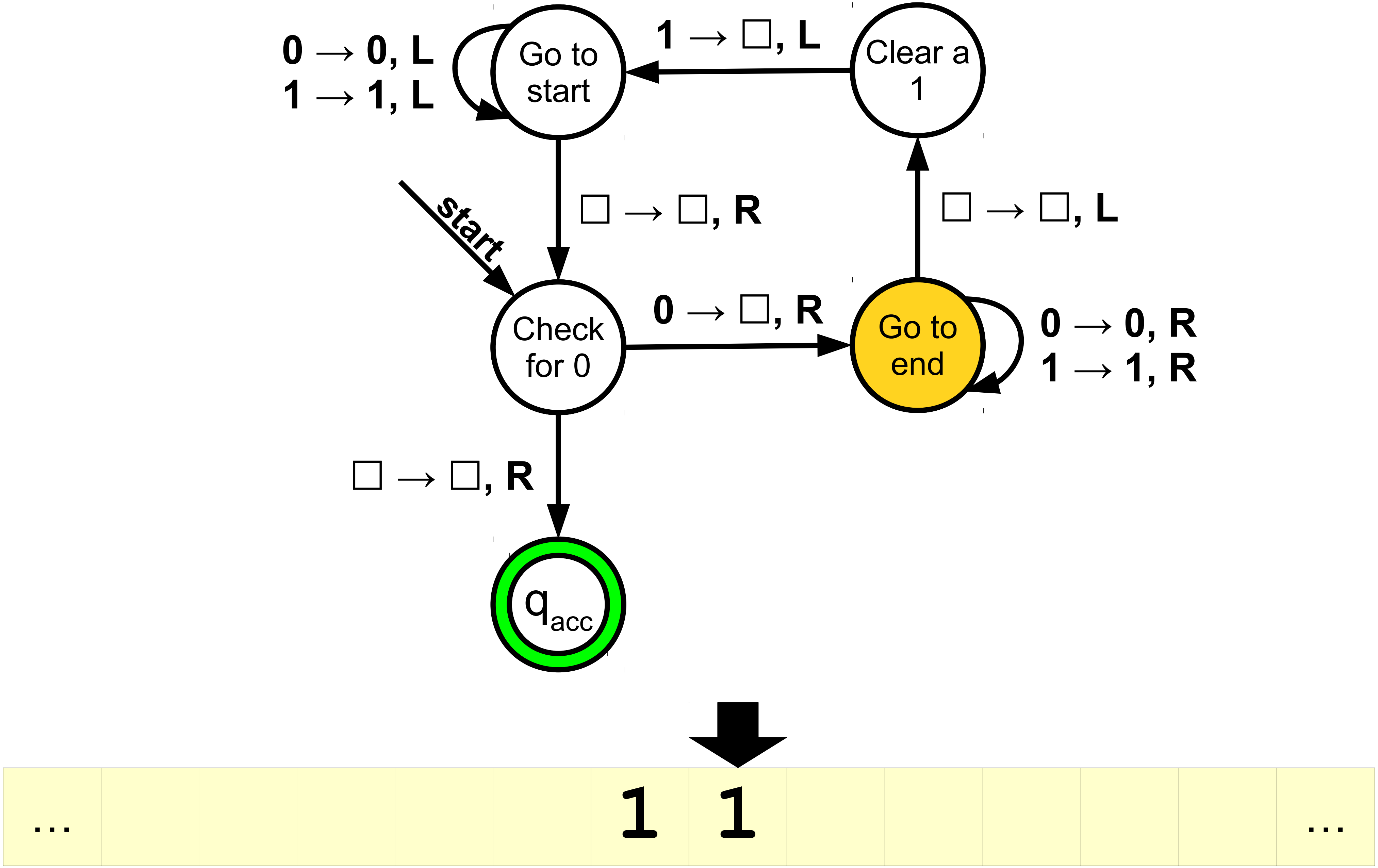

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}
…
0
1
1
…

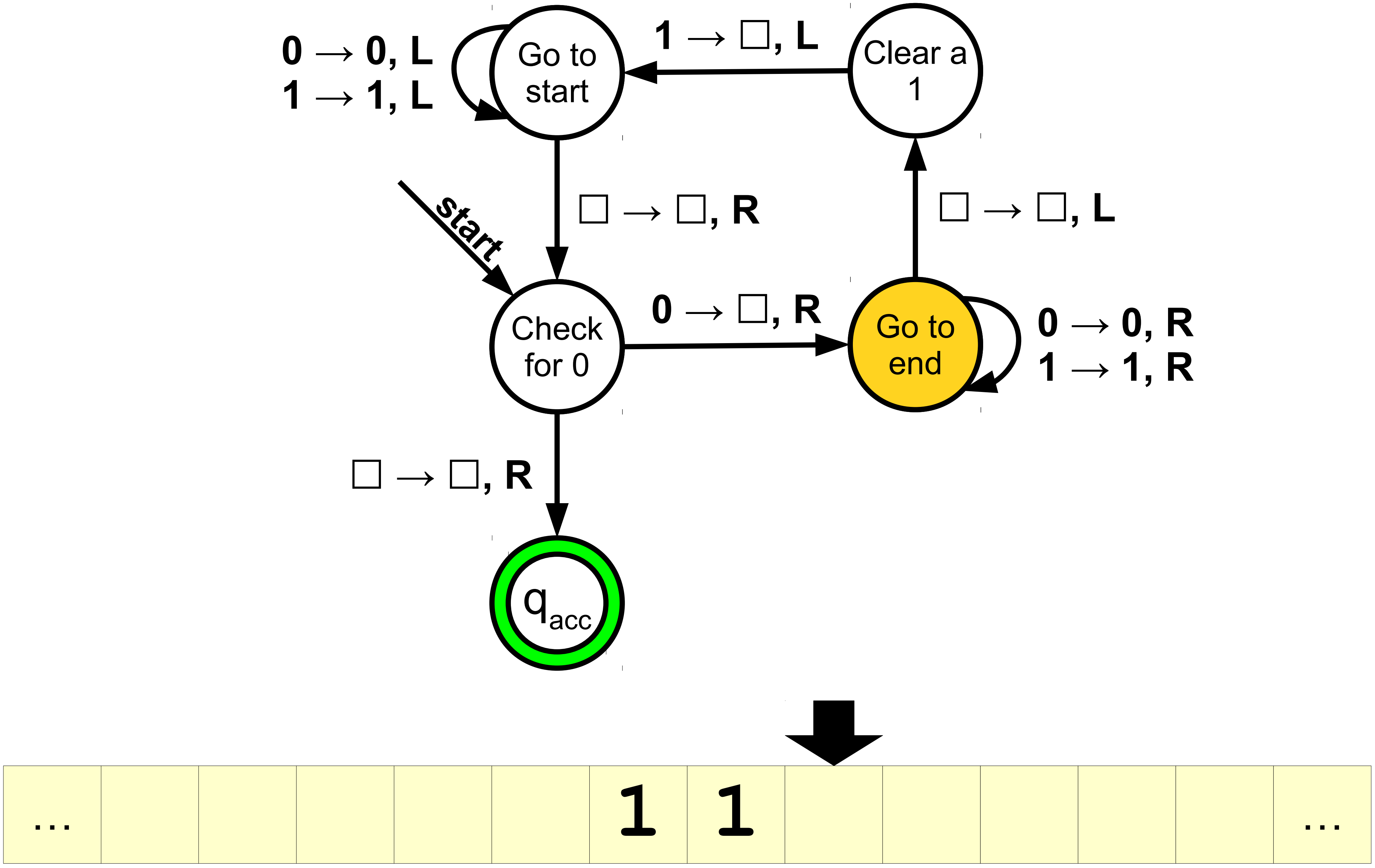

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}
…
0
1
1
…

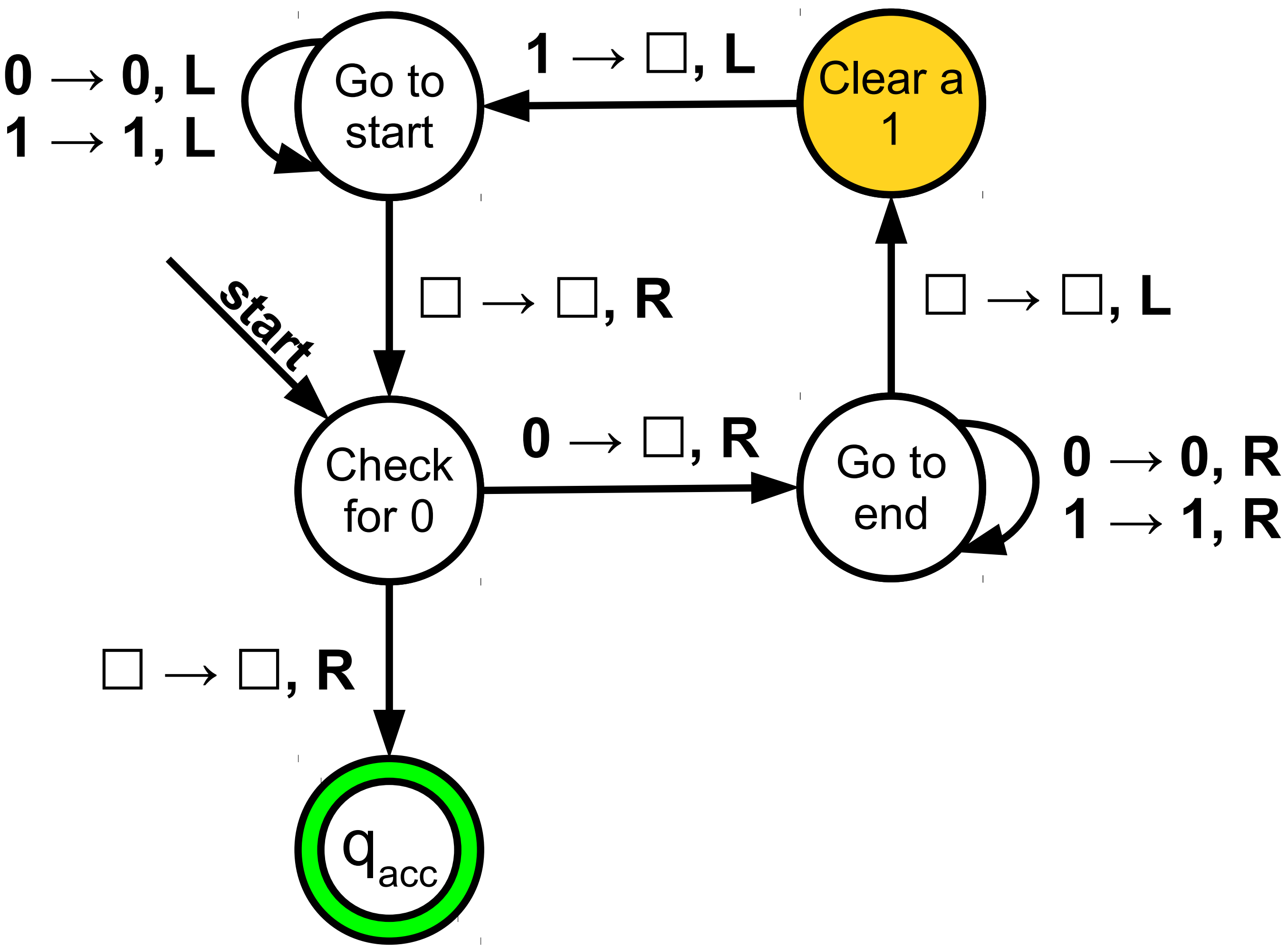

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
□ → □, R
start
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}
…
0
1
1
…

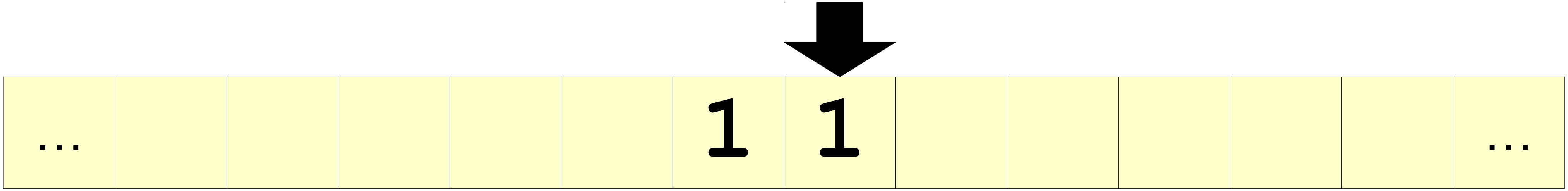

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}

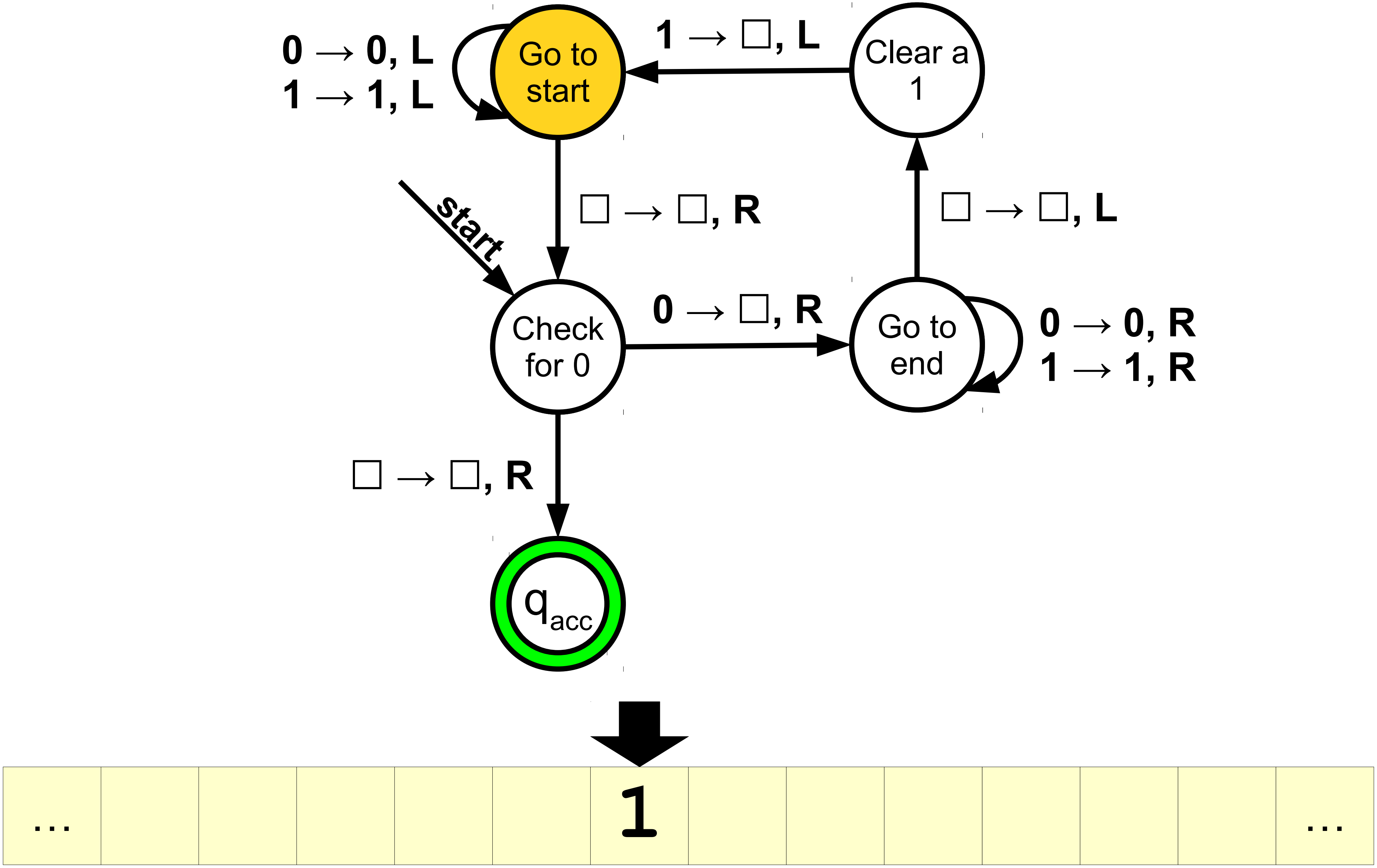
...						1	1						...

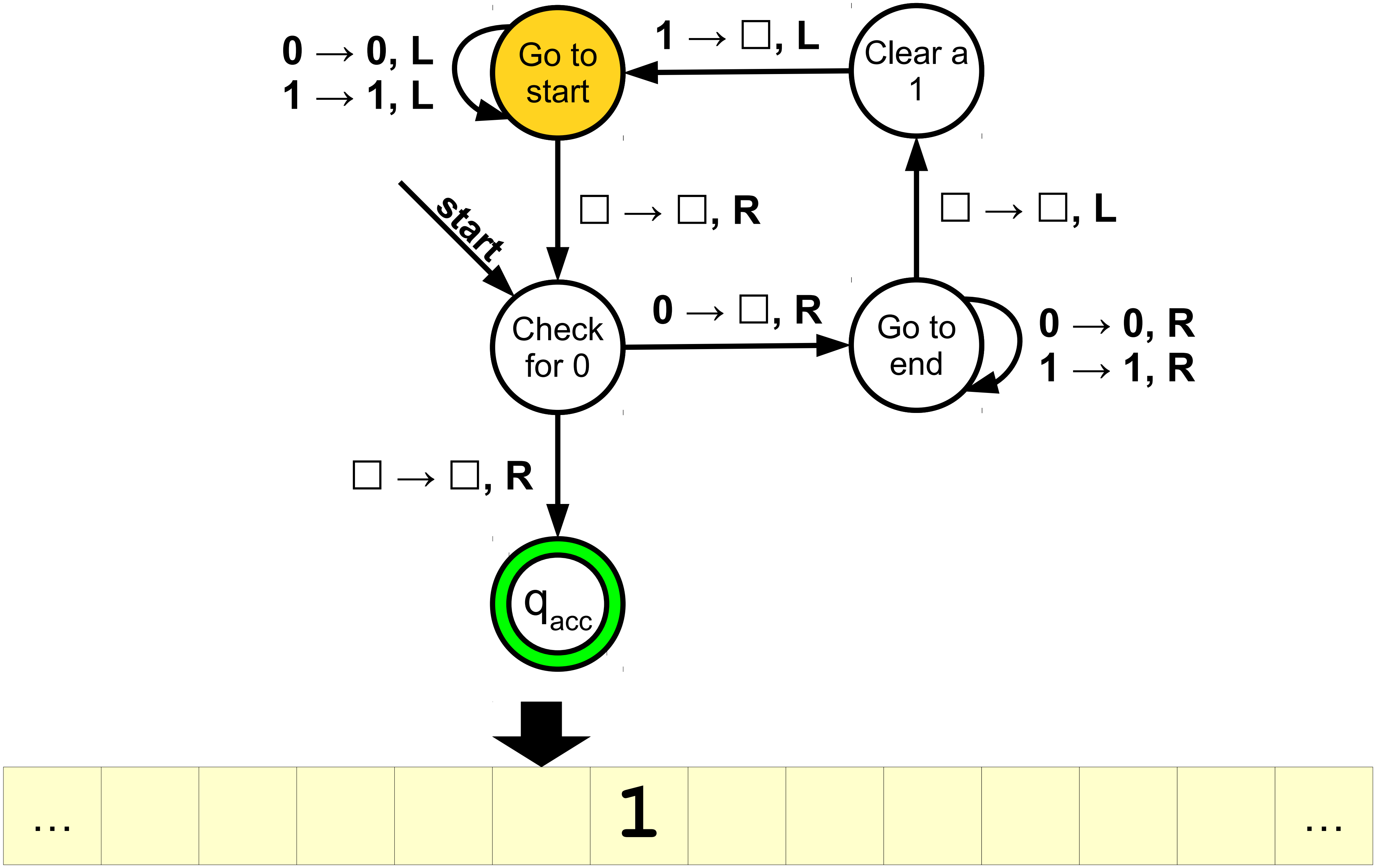

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}
…
1
1
…

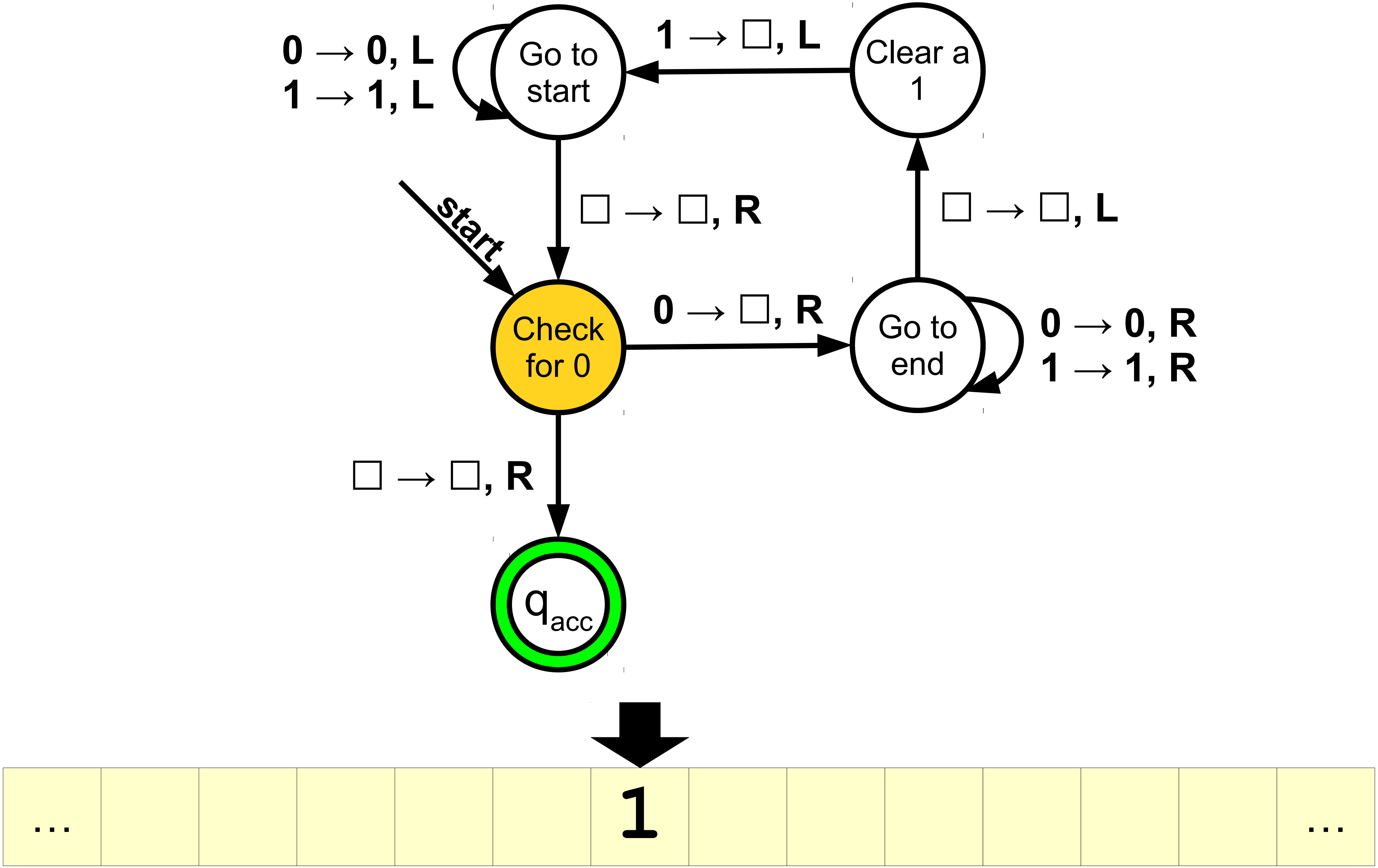

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}
…
1
1
…

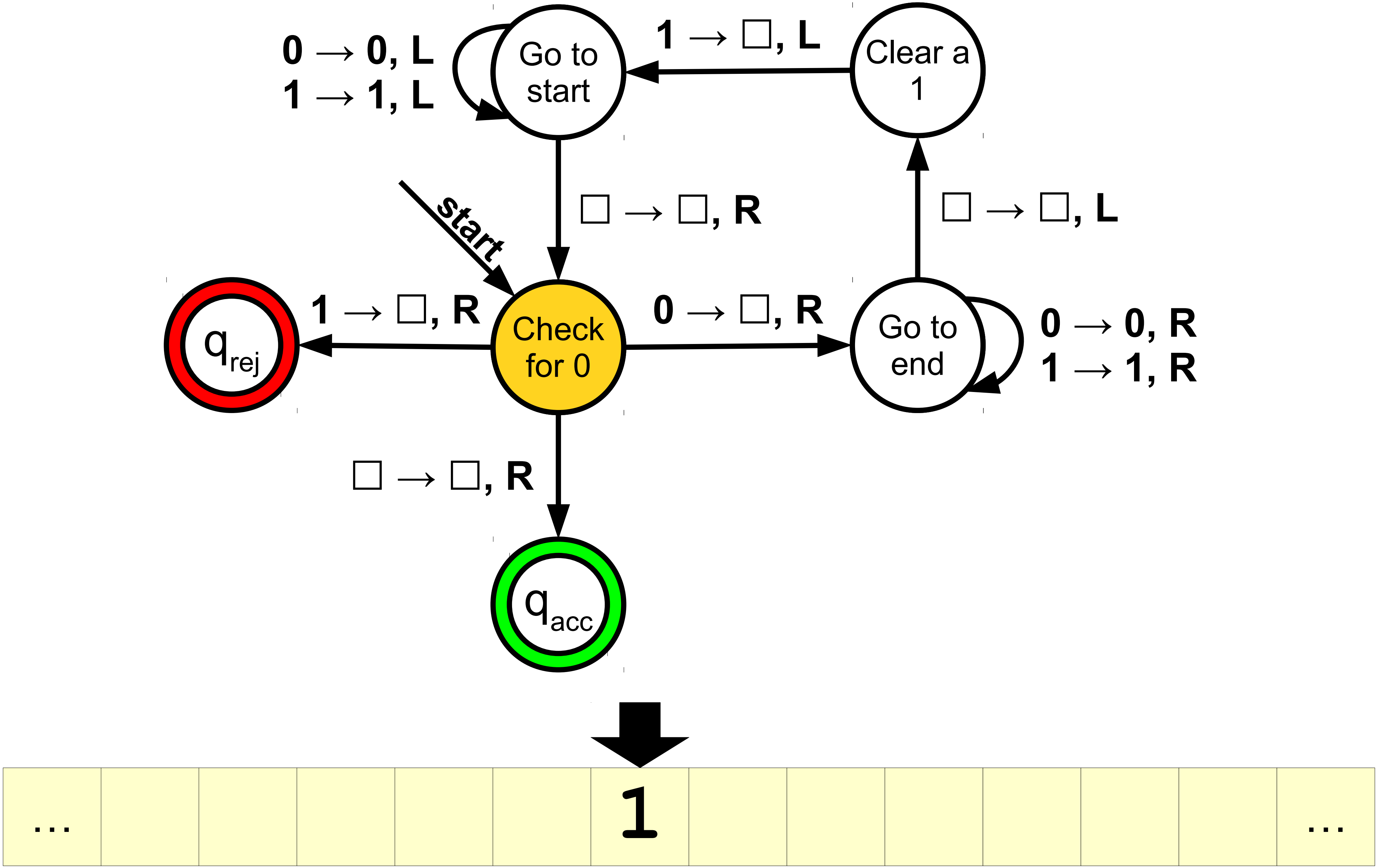

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}

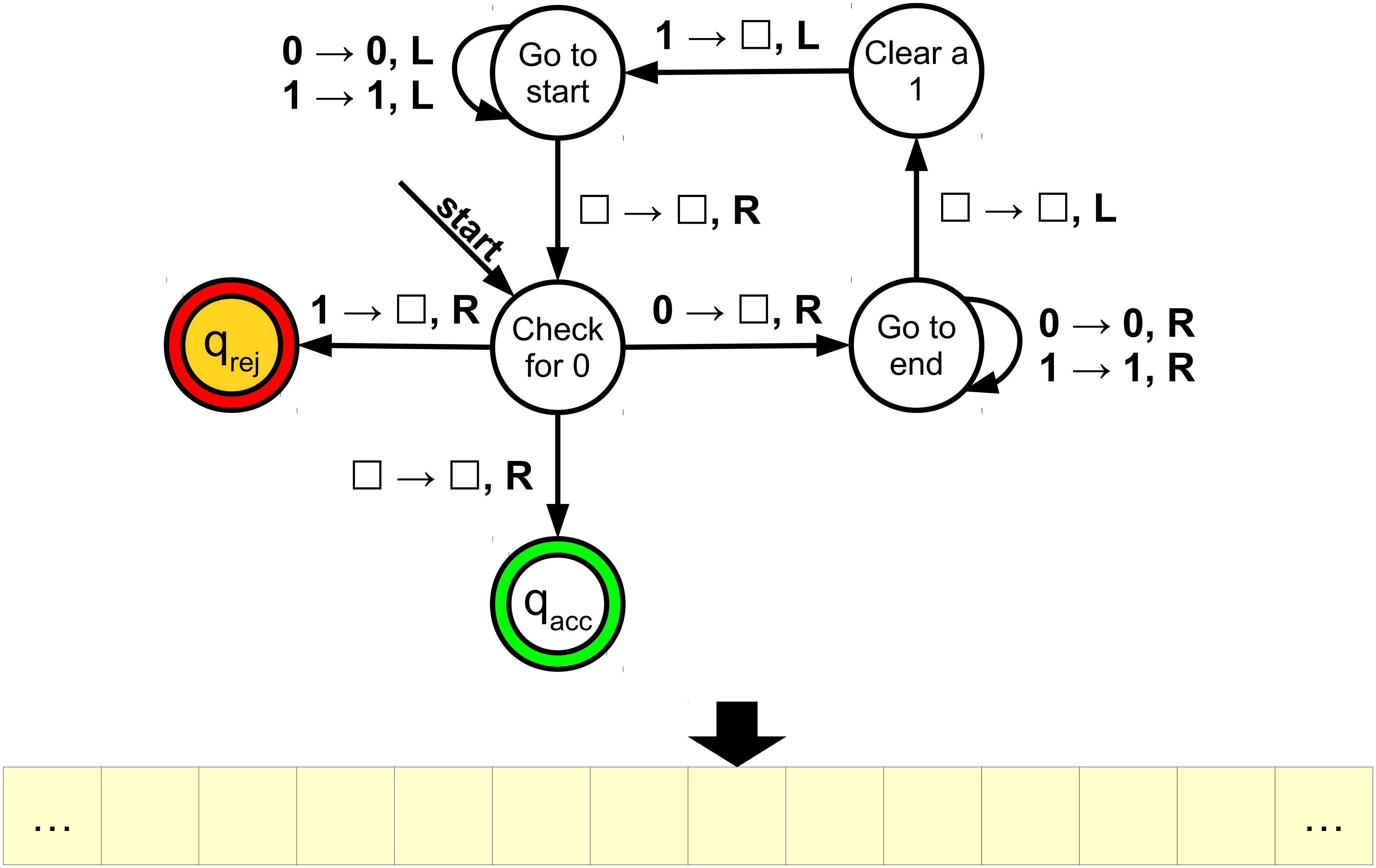

…
1
1
…

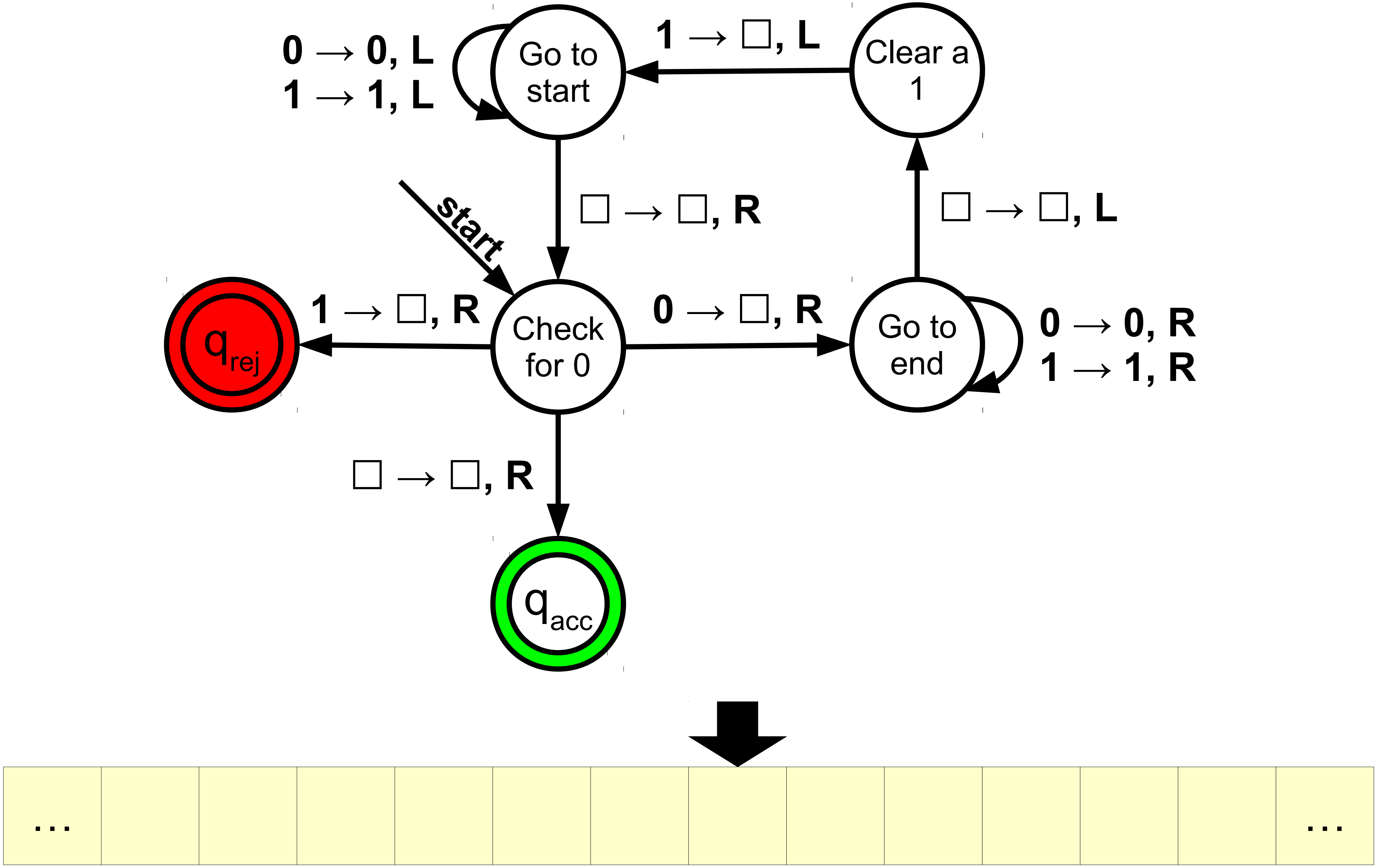

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
□ → □, R
start
□ → □, L
0 → □, R
Check for 0
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
...
1
...

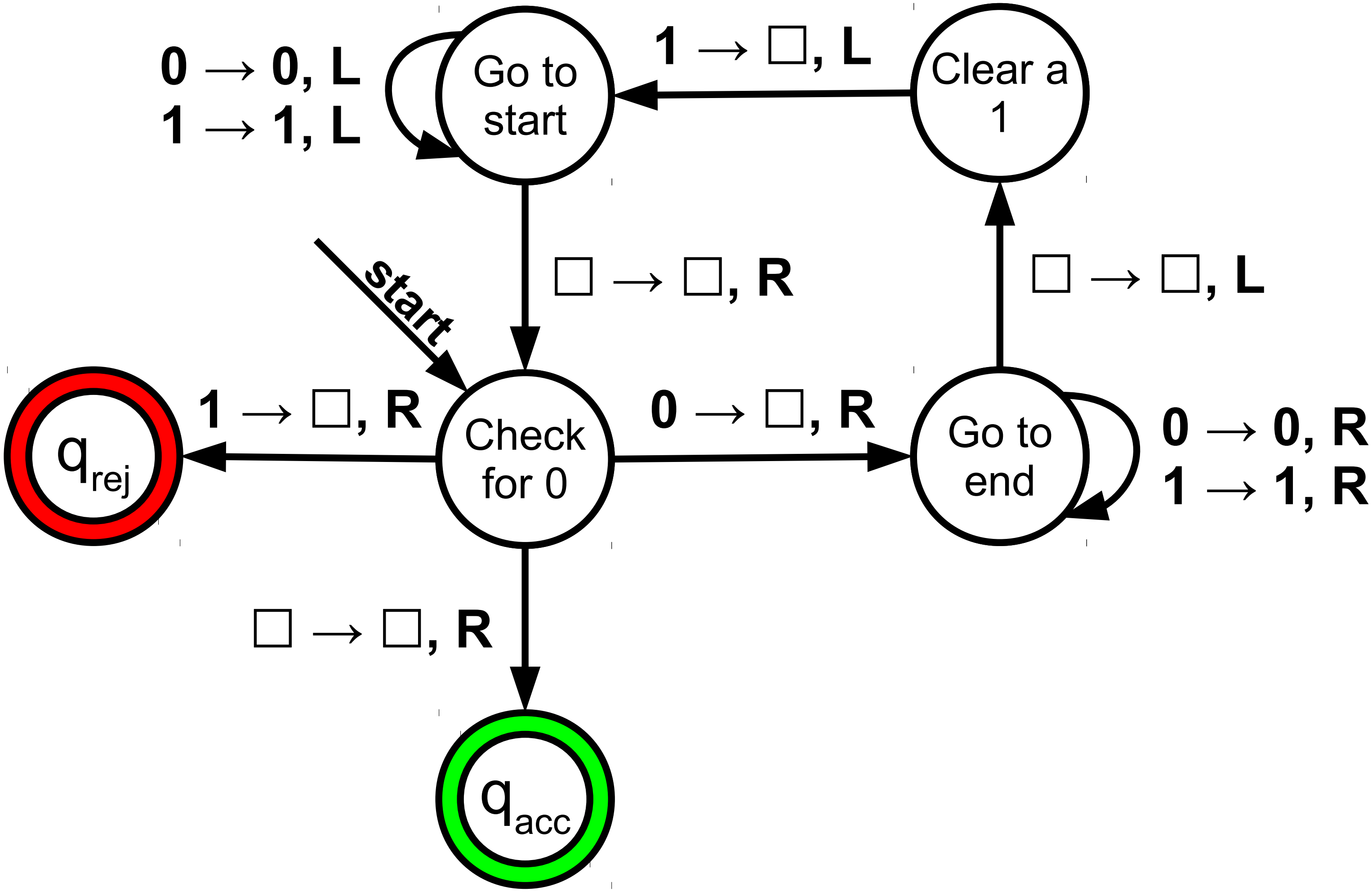

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}
…
1
…


0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}
…
1
…

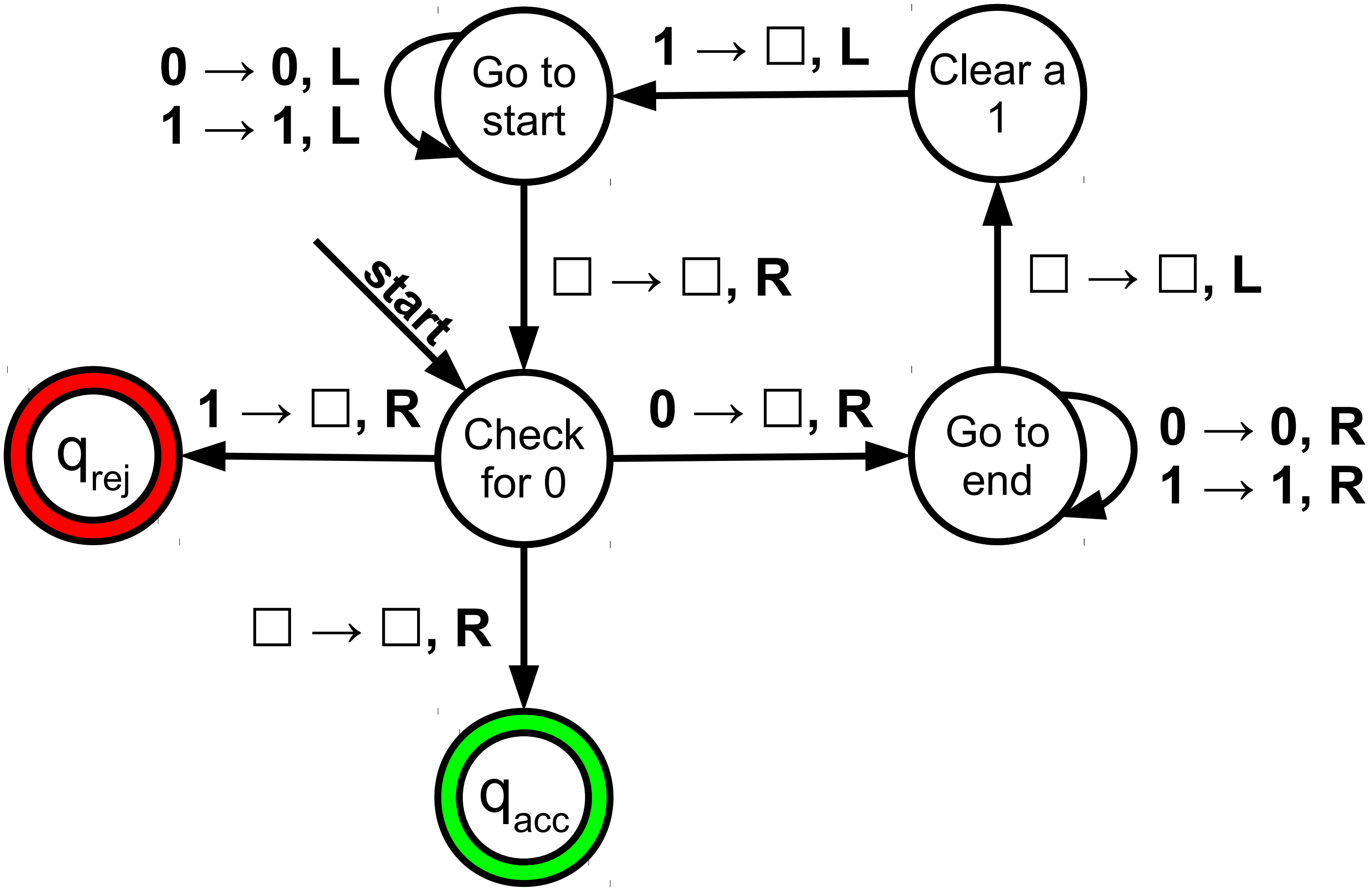

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
1
…

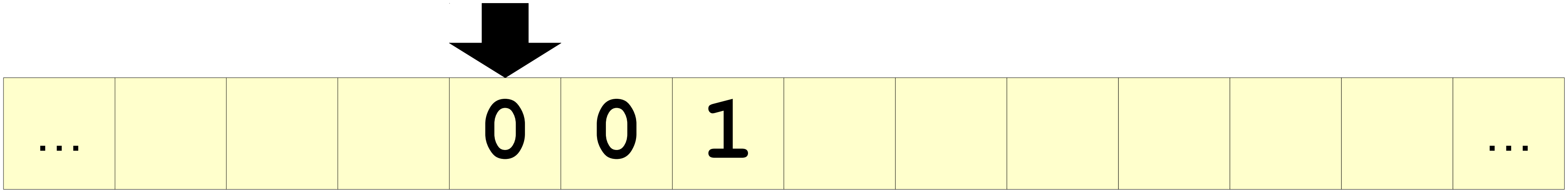

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
q_rej
□ → □, R
q_acc
…
…

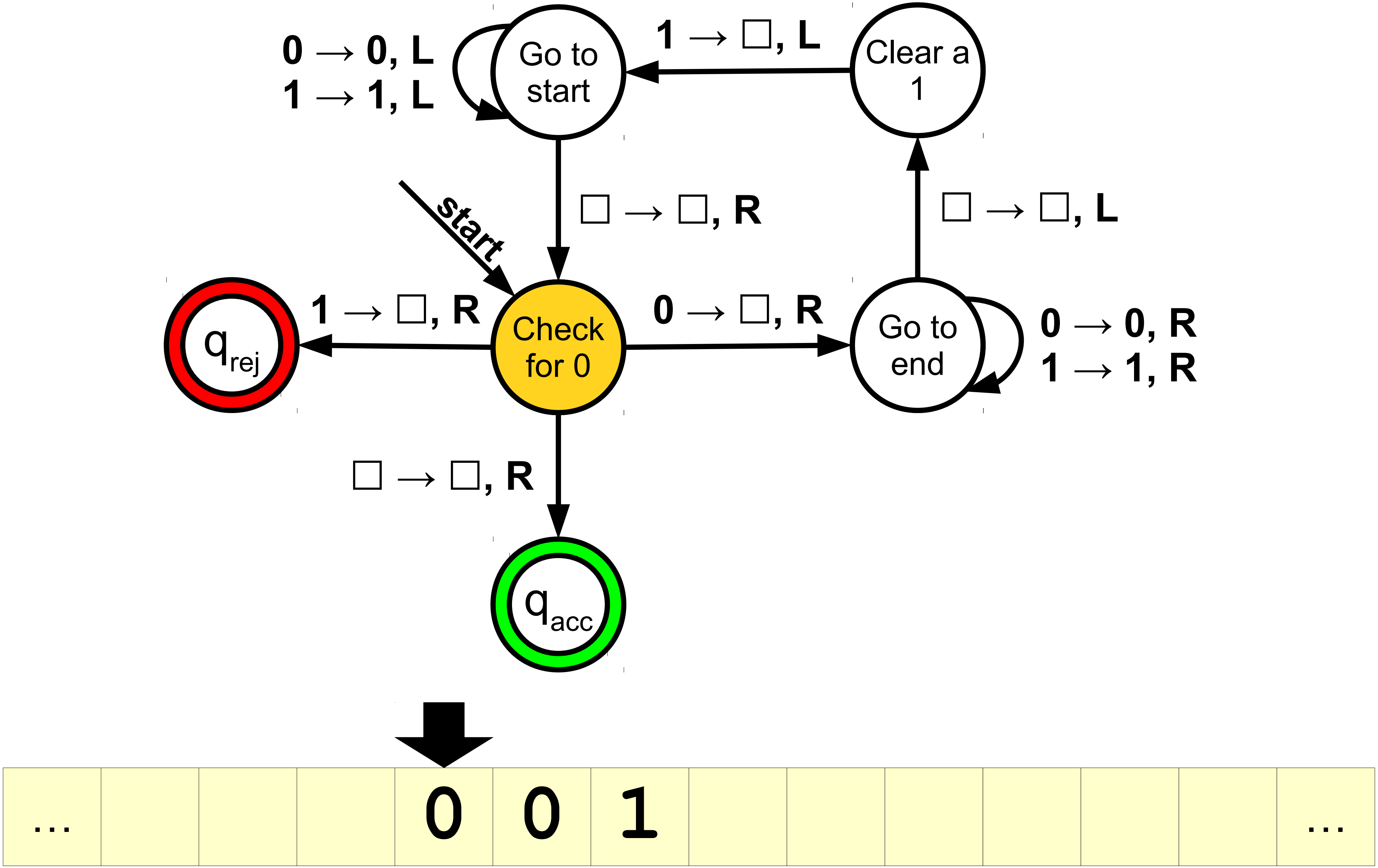

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
…

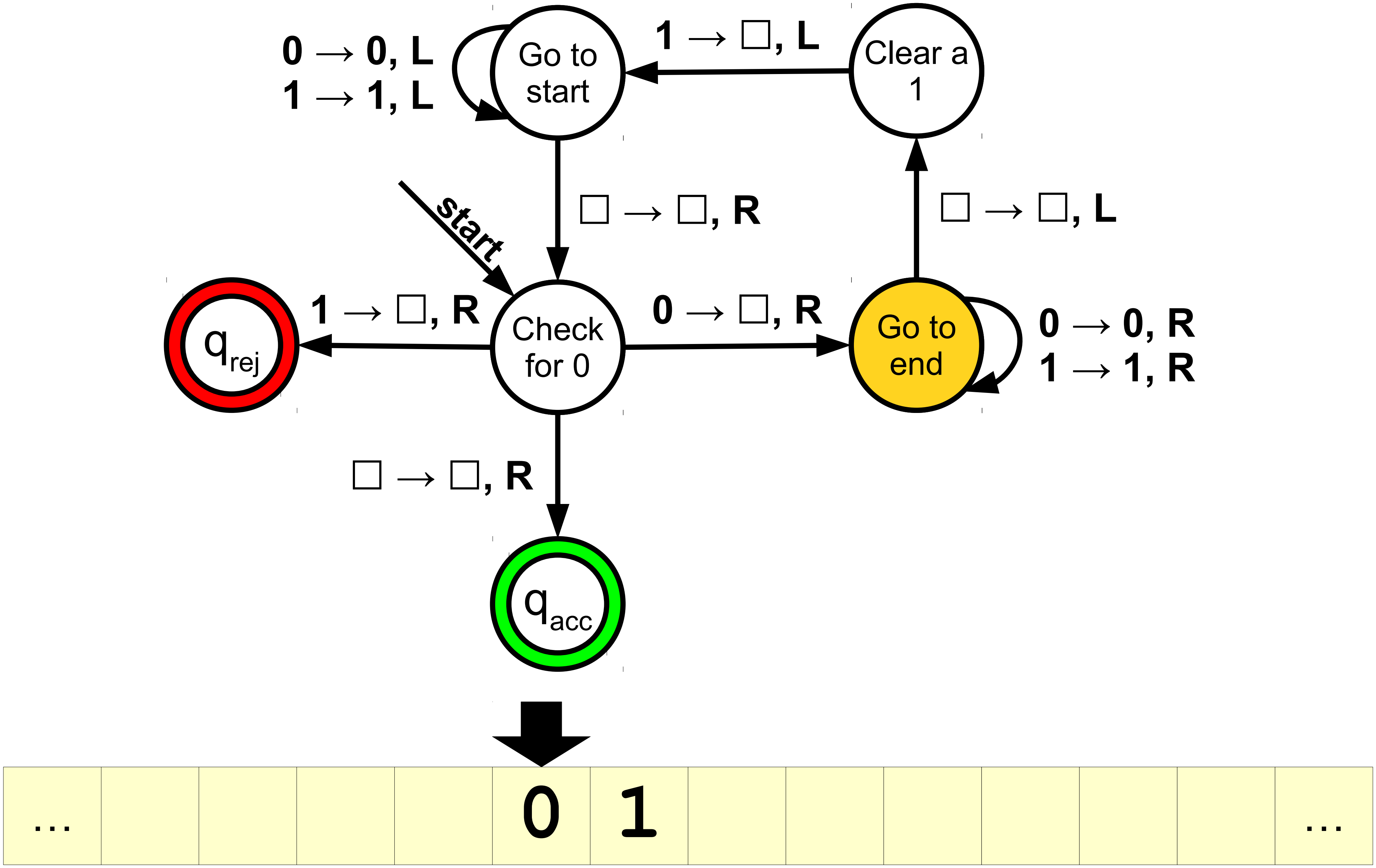


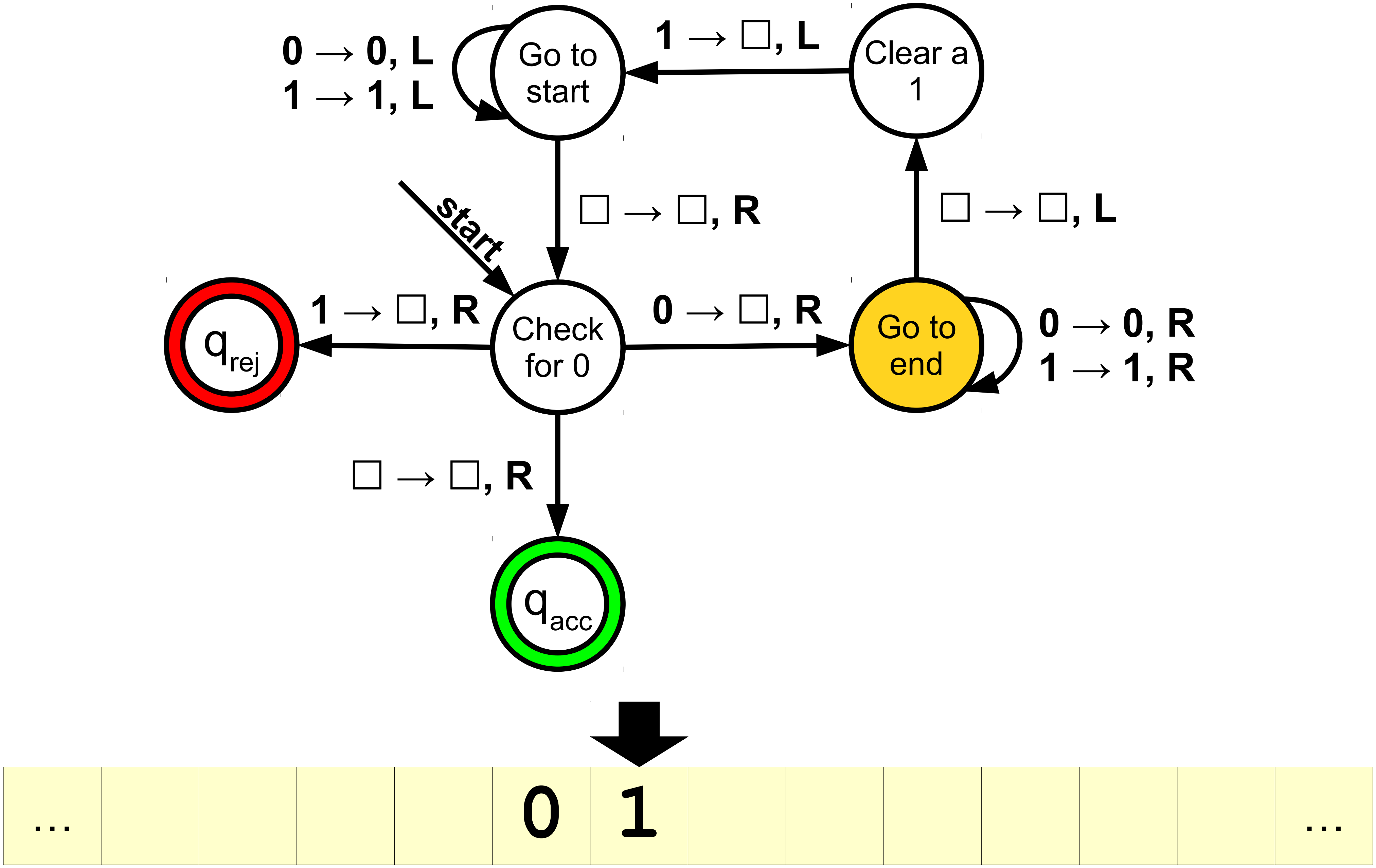
0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
□ → □, R
□ → □, L
start
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
q_{rej}
□ → □, R
q_{acc}

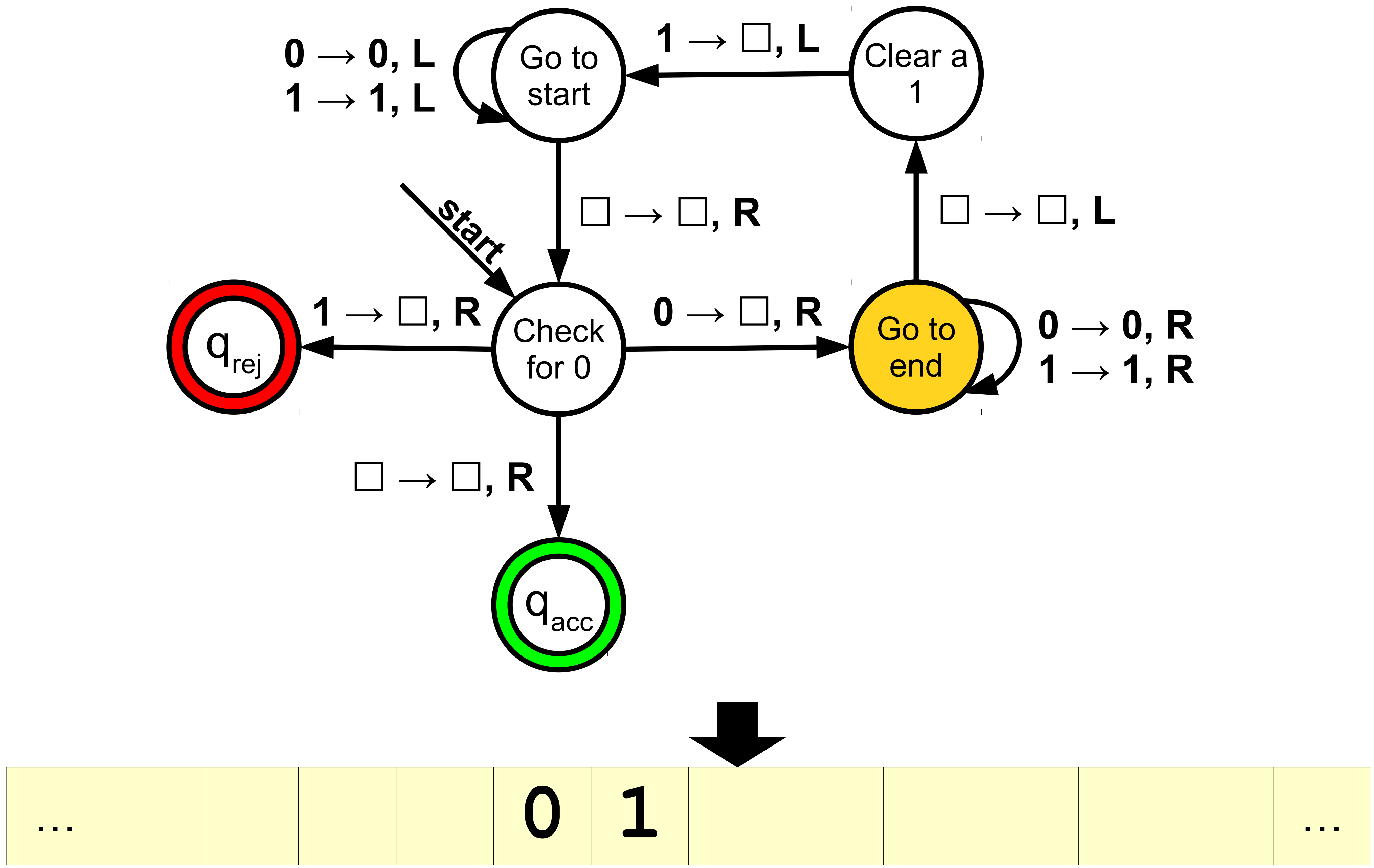

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
□ → □, R
□ → □, L
start
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
q_{rej}
□ → □, R
q_{acc}


…
0
0
1
…

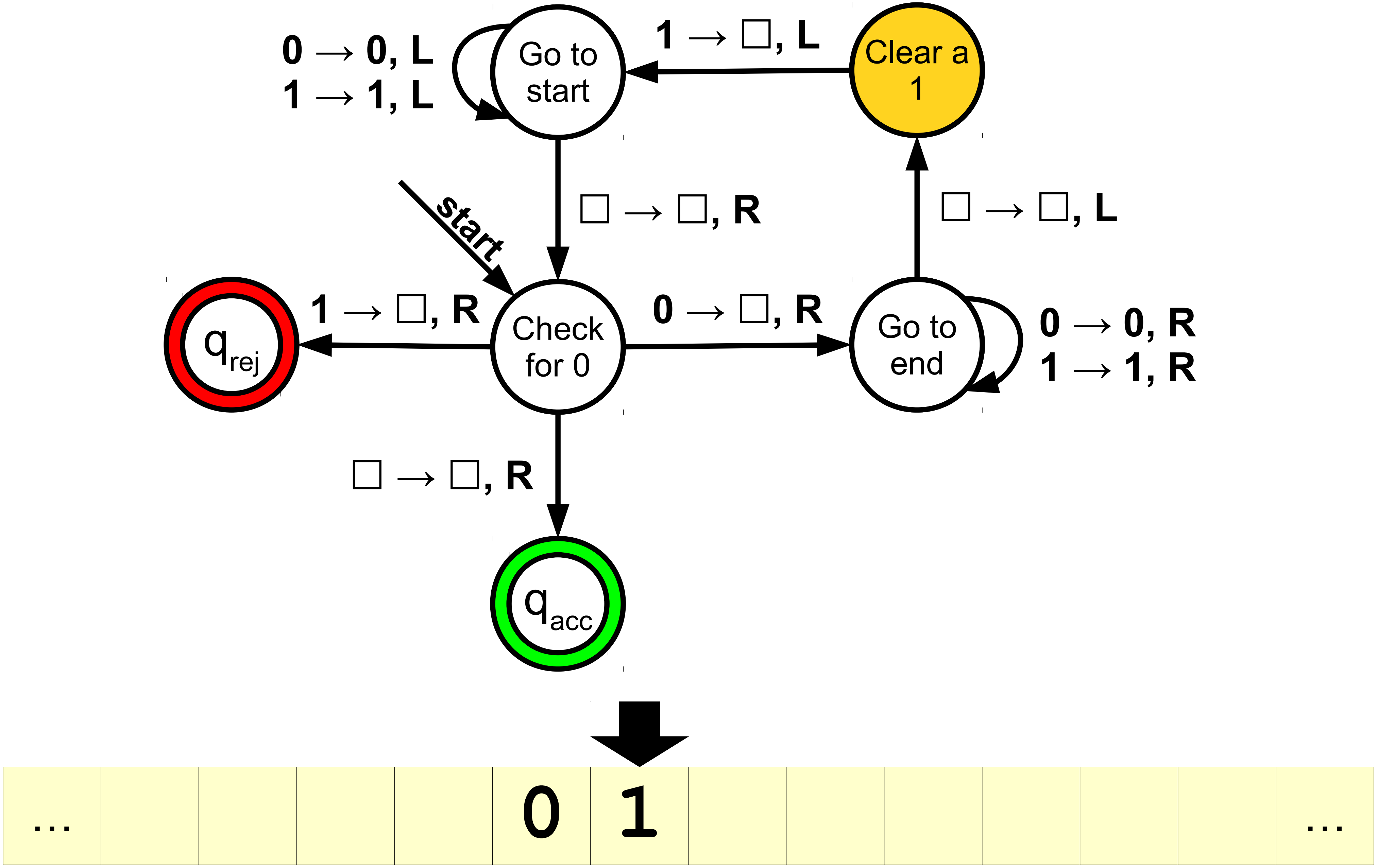

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
□ → □, R
start
□ → □, L
1 → □, R
q_rej
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
0
0
1
…

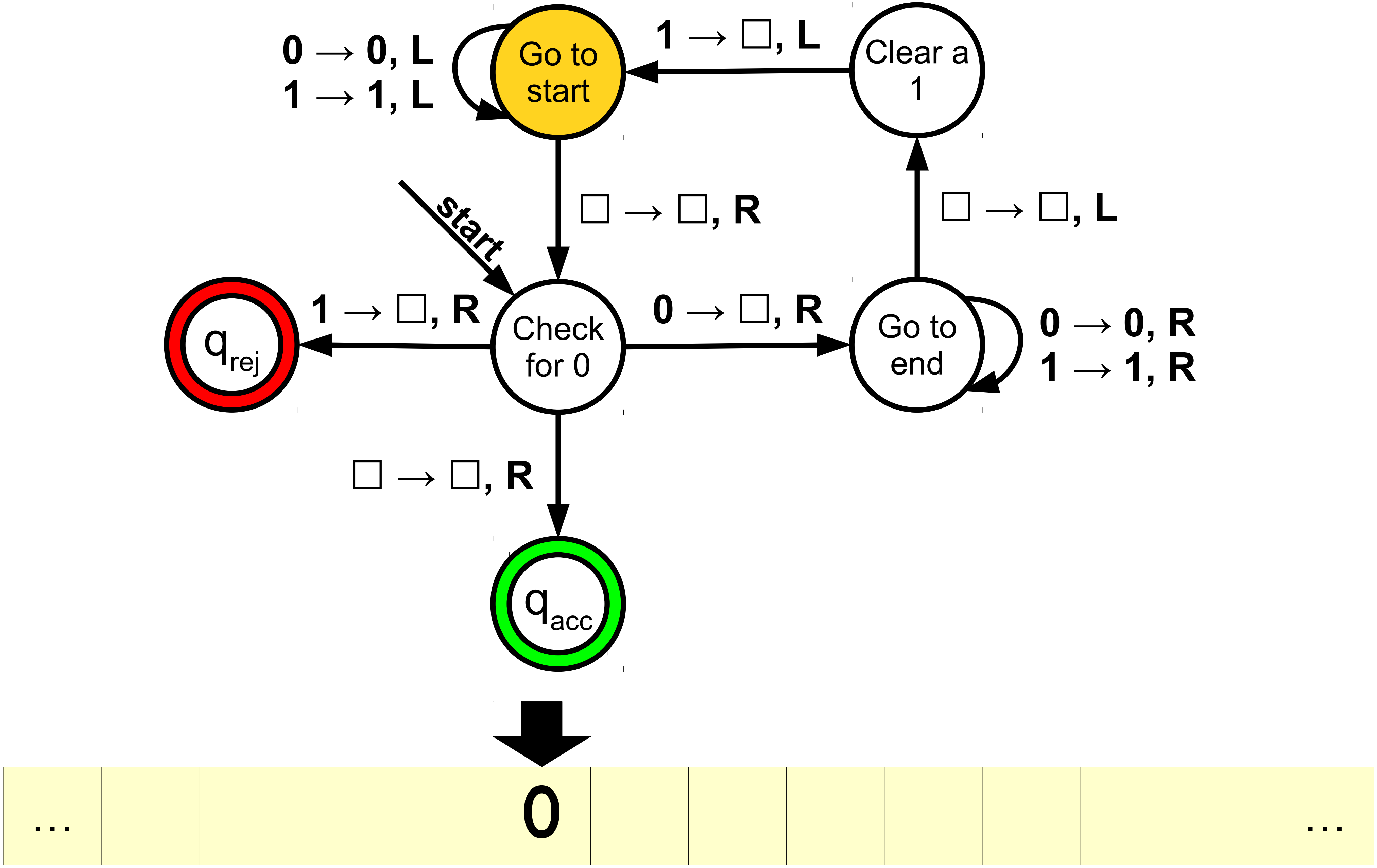

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
□ → □, R
□ → □, L
start
1 → □, R
q_rej
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
0
1
…

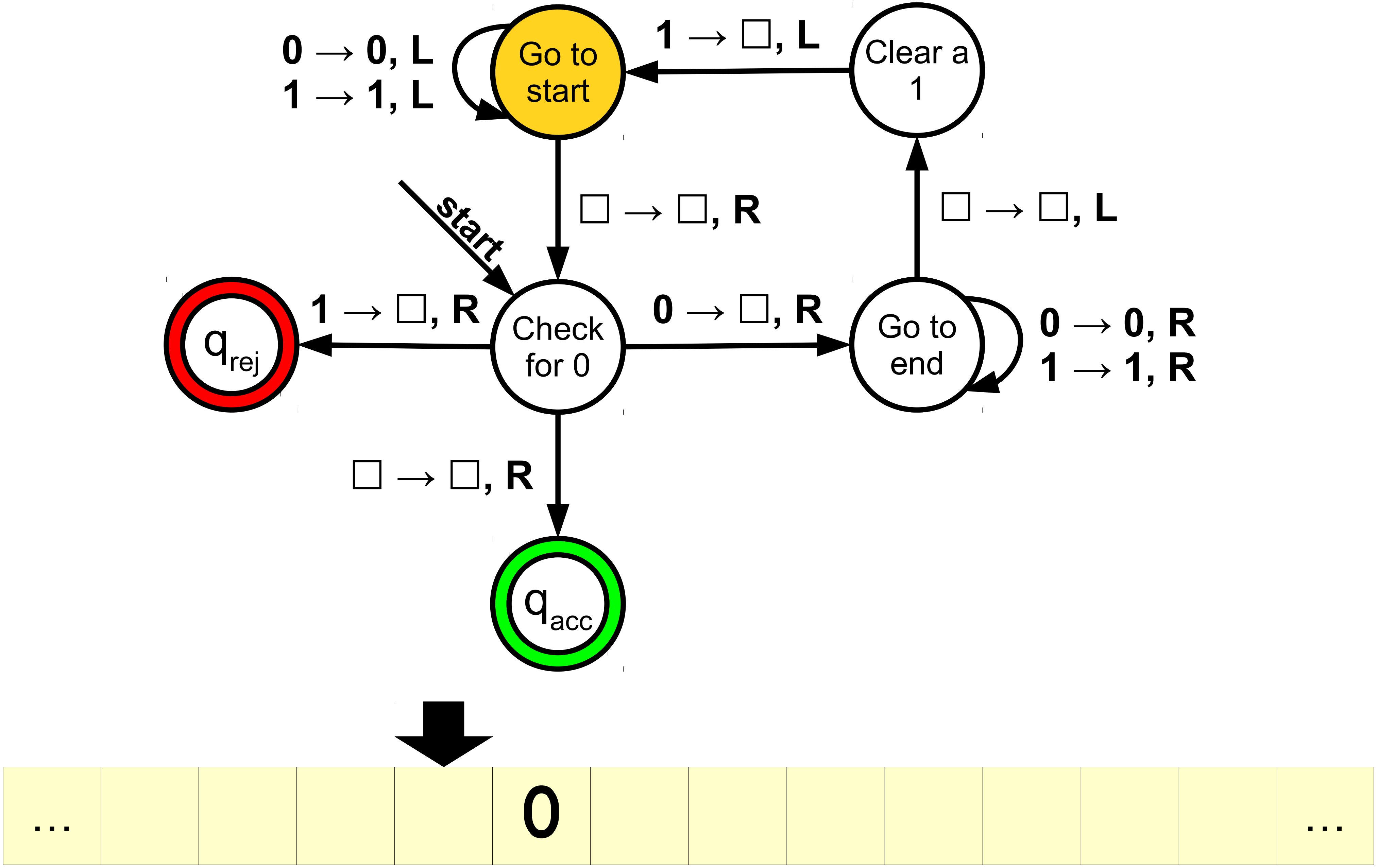

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
□ → □, R
□ → □, L
start
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
0
1
…

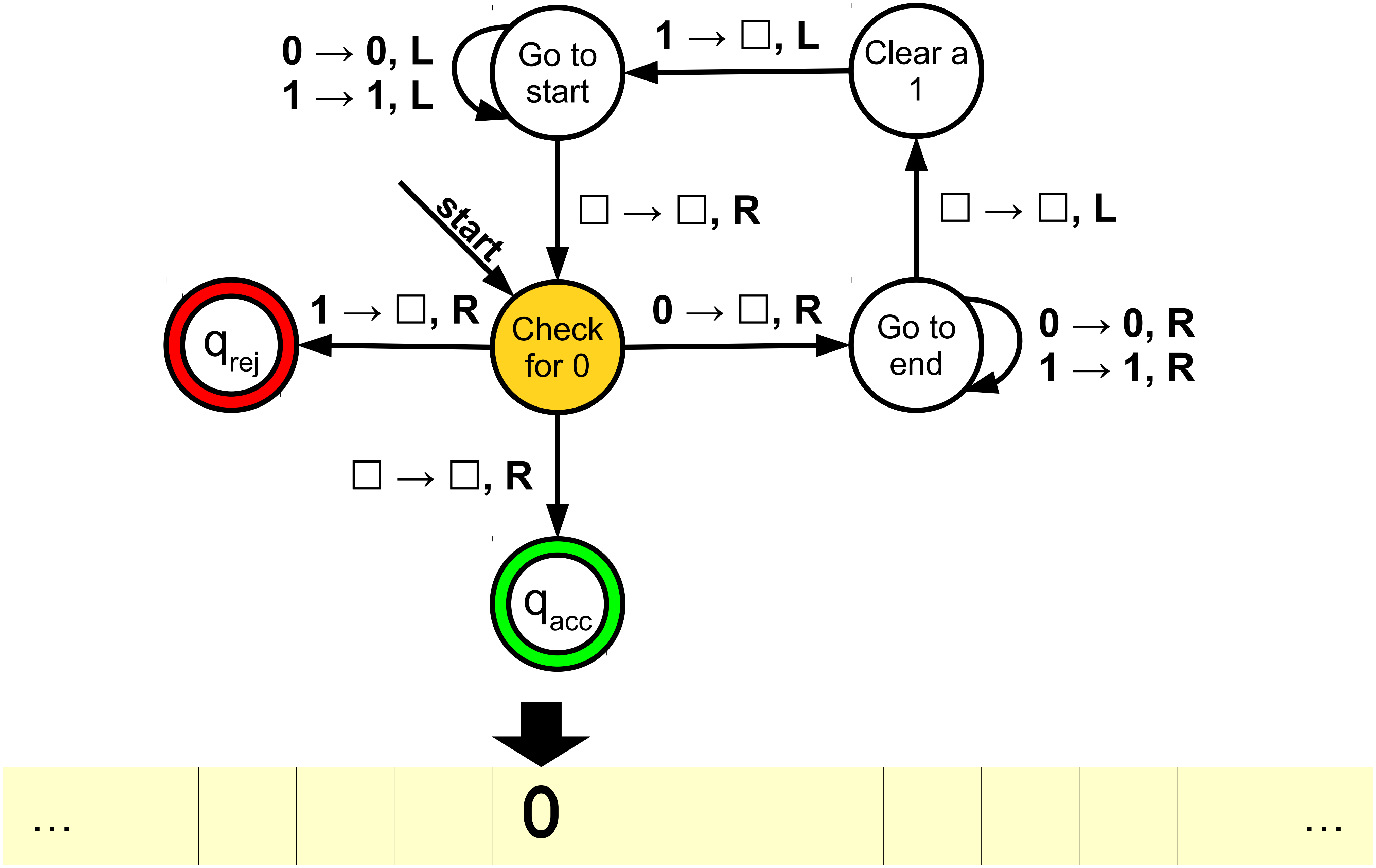


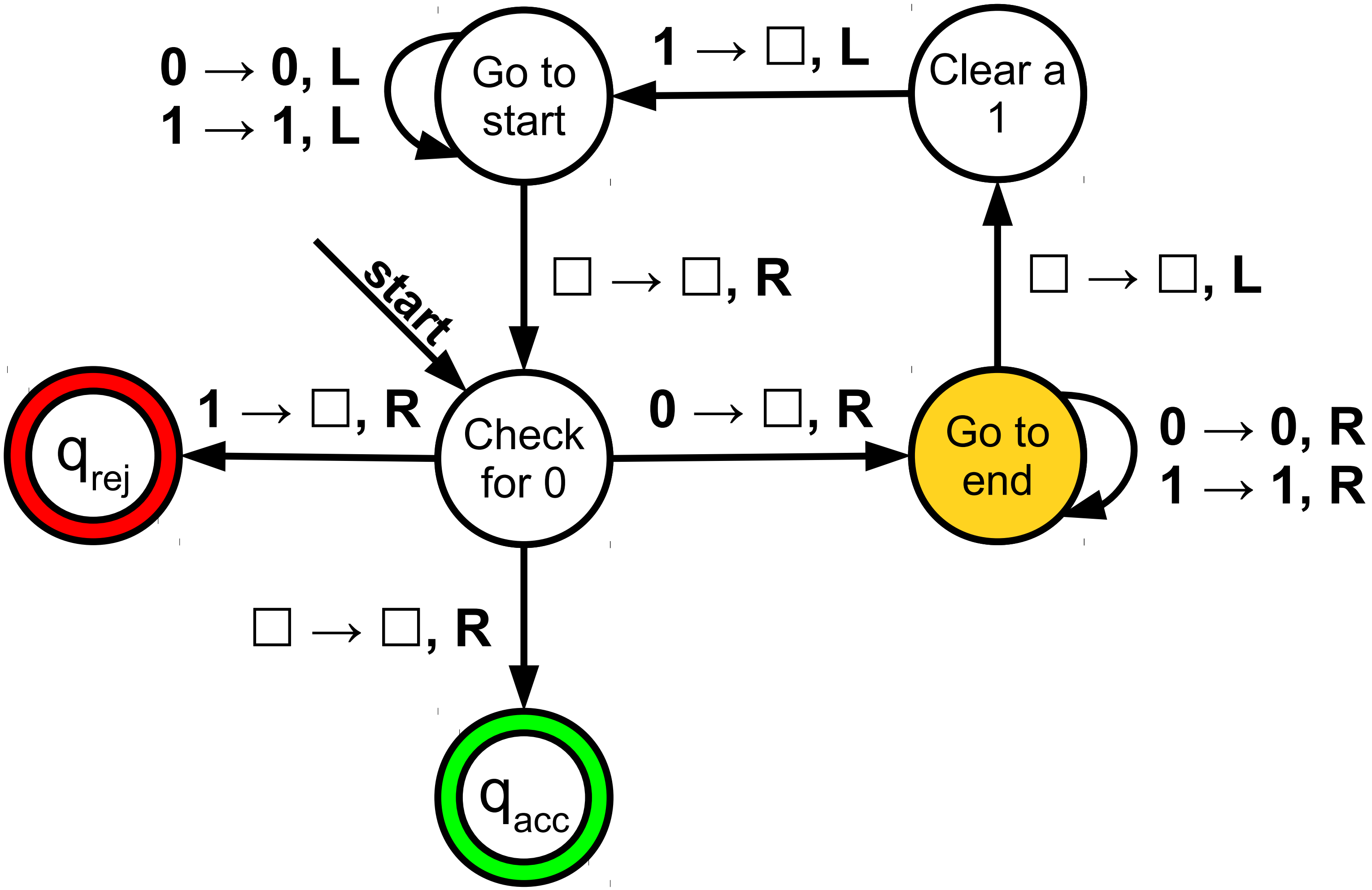
0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
□ → □, R
□ → □, L
start
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
0
1
…

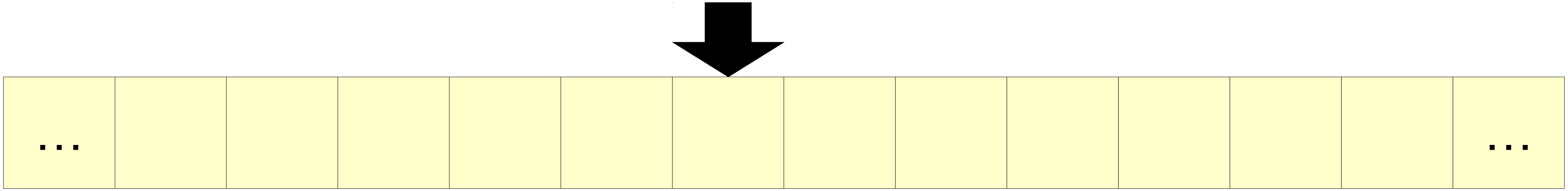

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
0
1
…

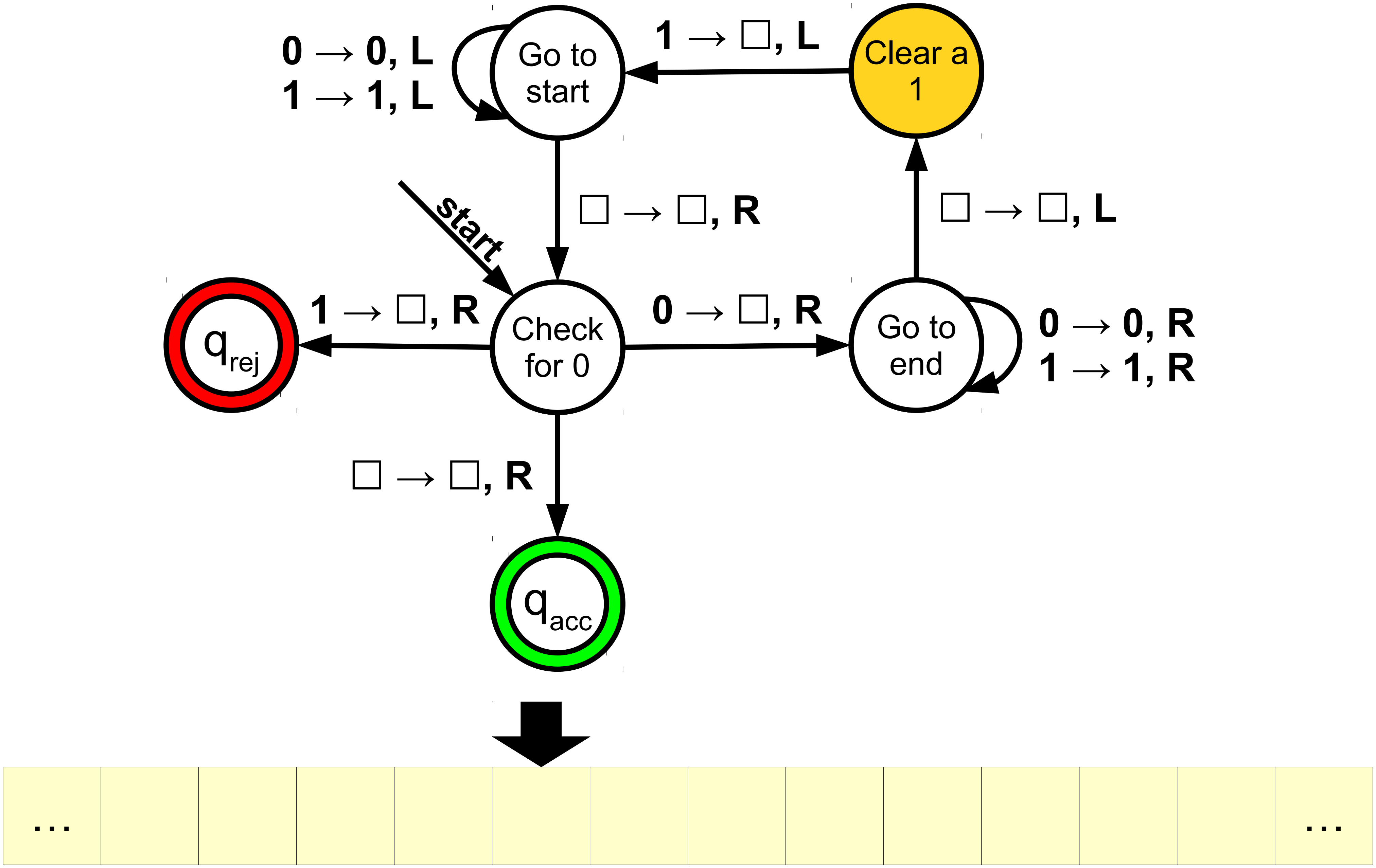

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
□ → □, R
start
□ → □, L
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
0
…

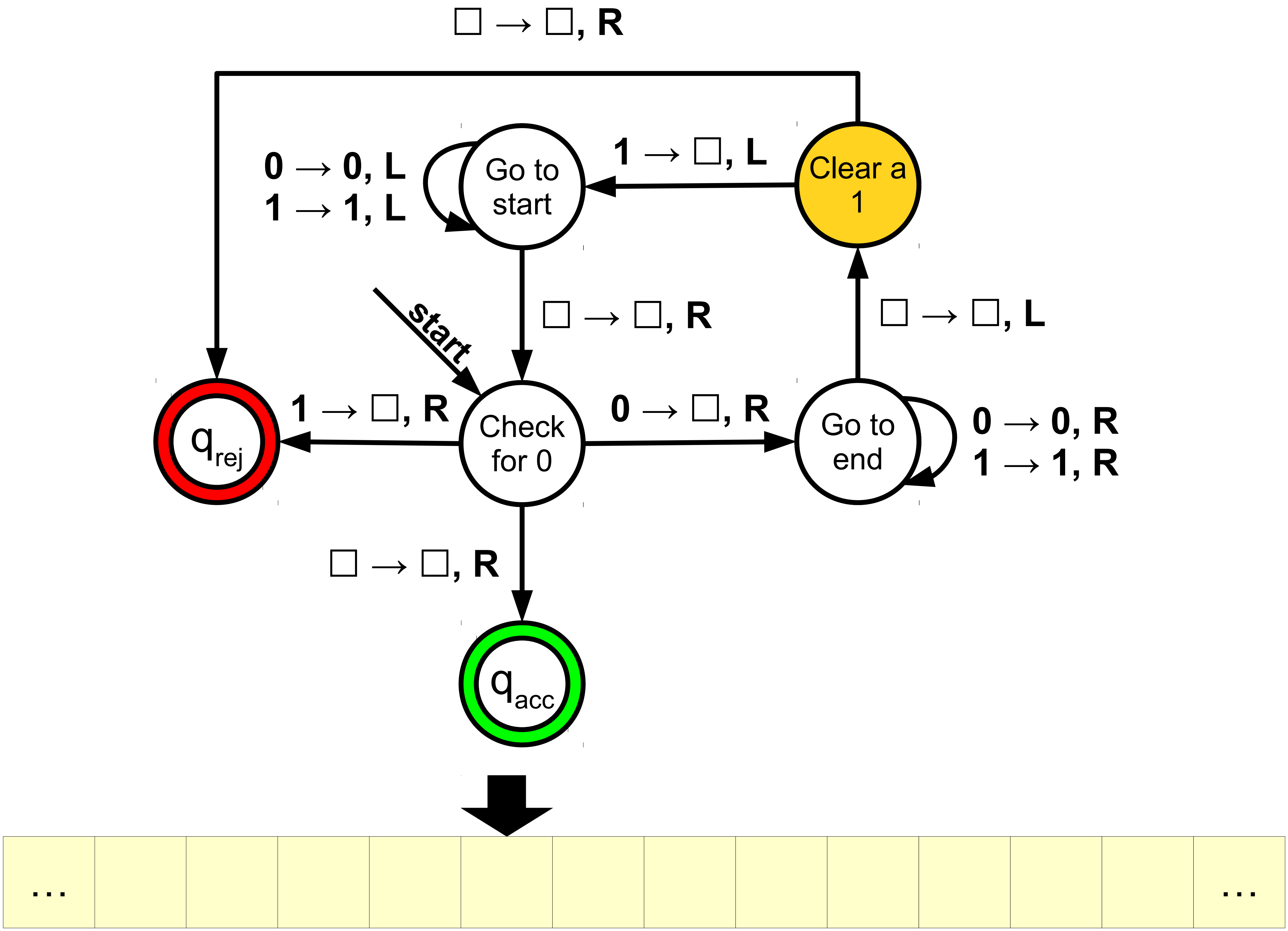

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
□ → □, R
start
□ → □, L
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
0
…

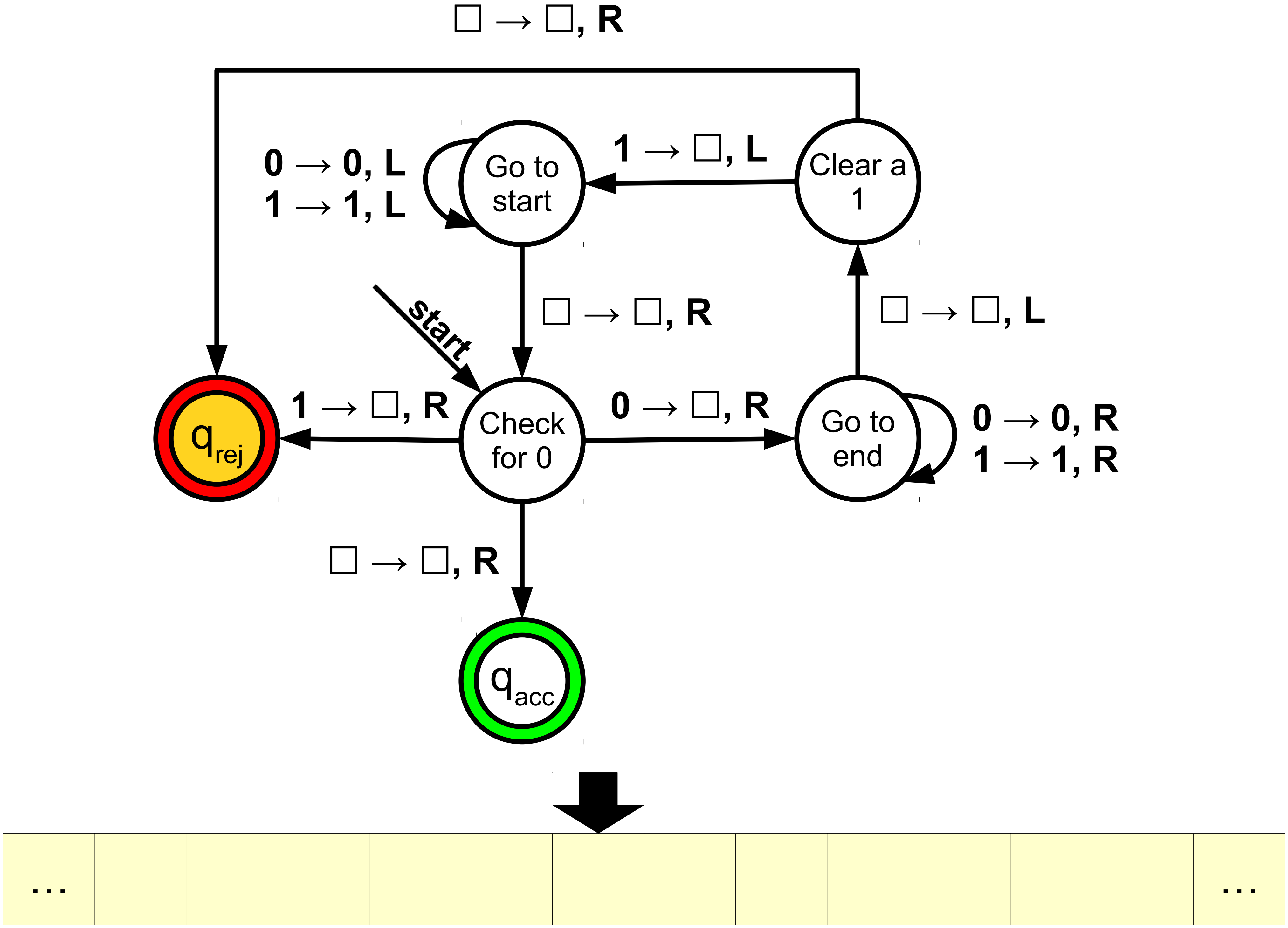

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
□ → □, R
□ → □, L
start
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
0
…

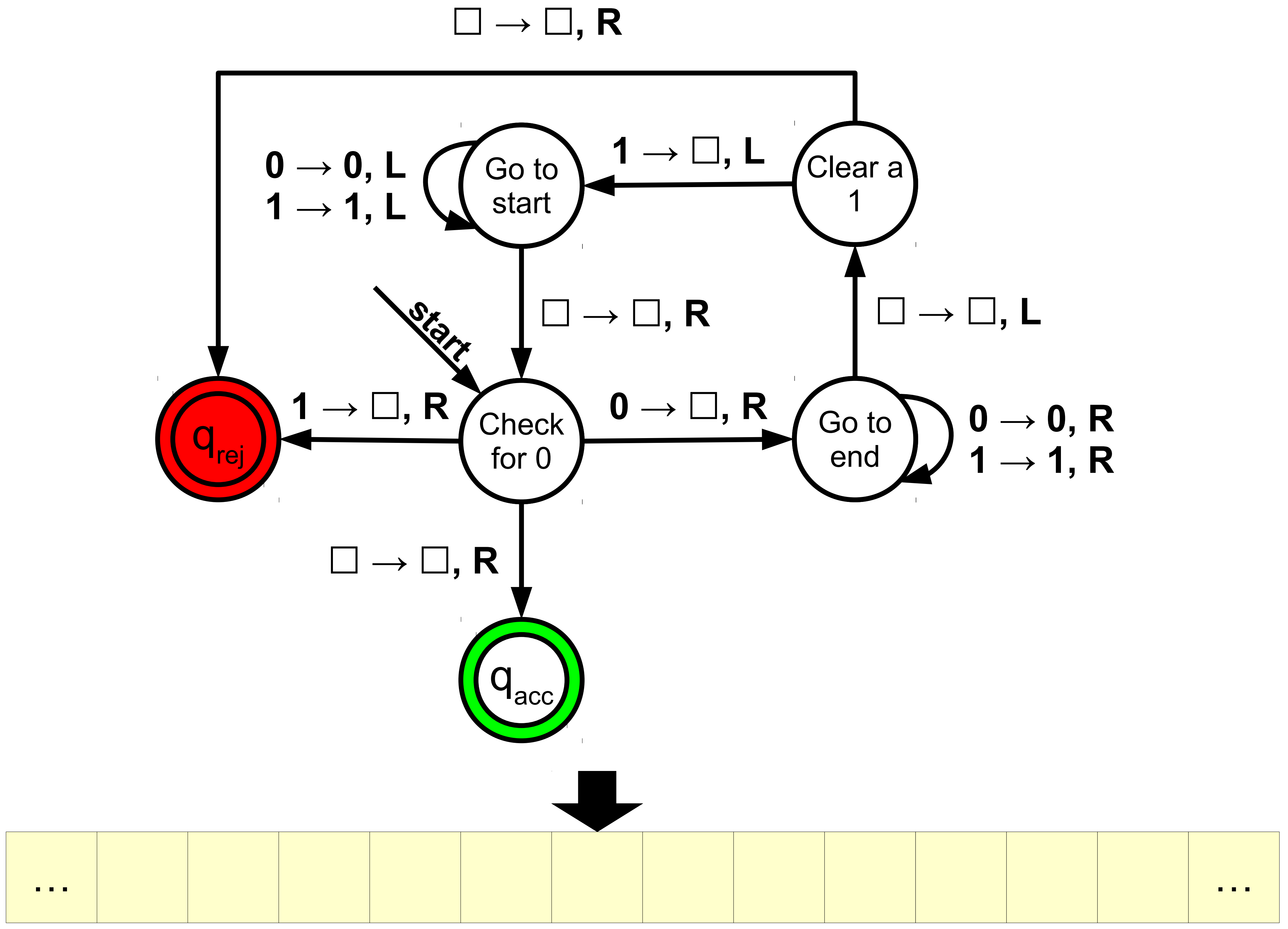

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
q_{rej}
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}

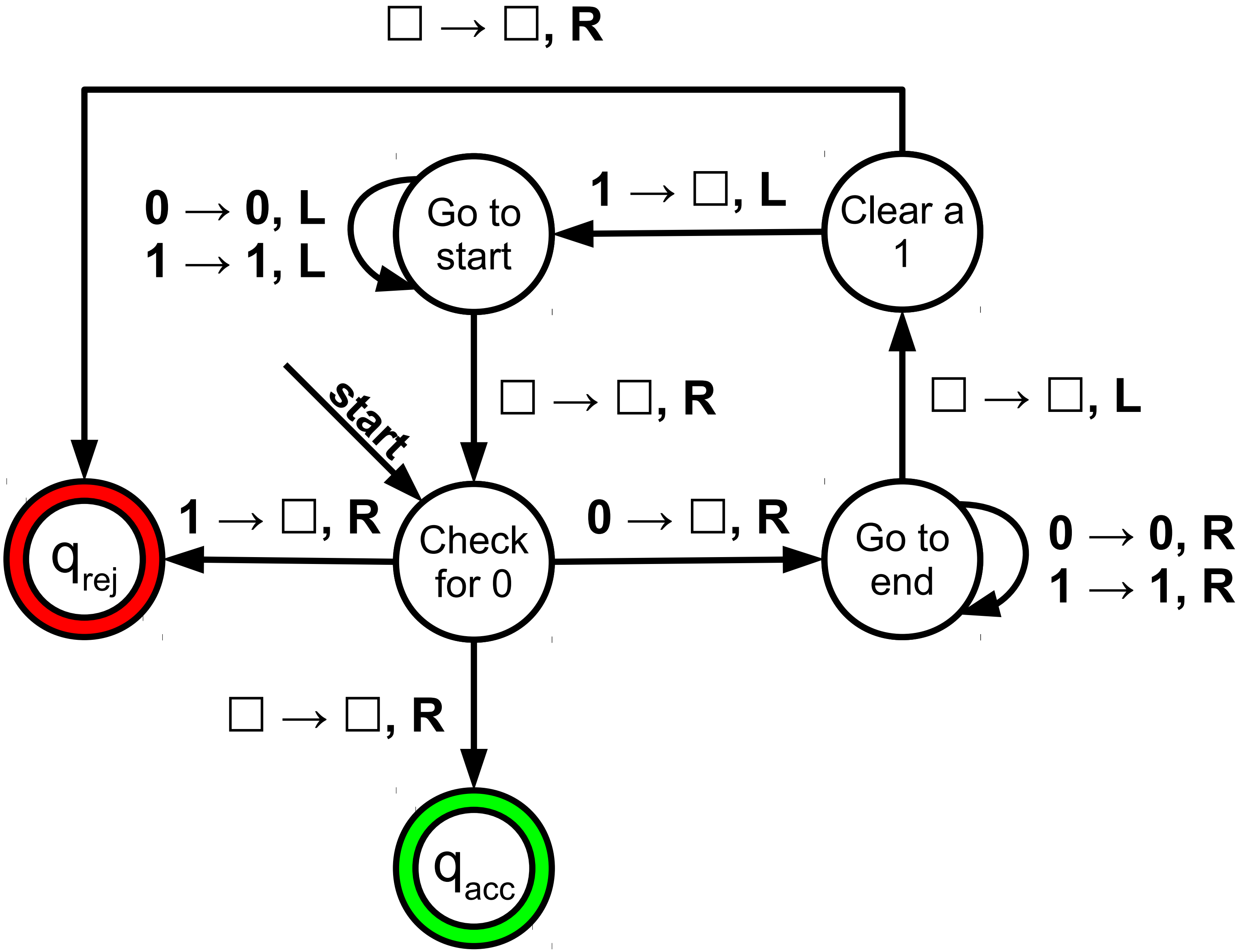

…
…

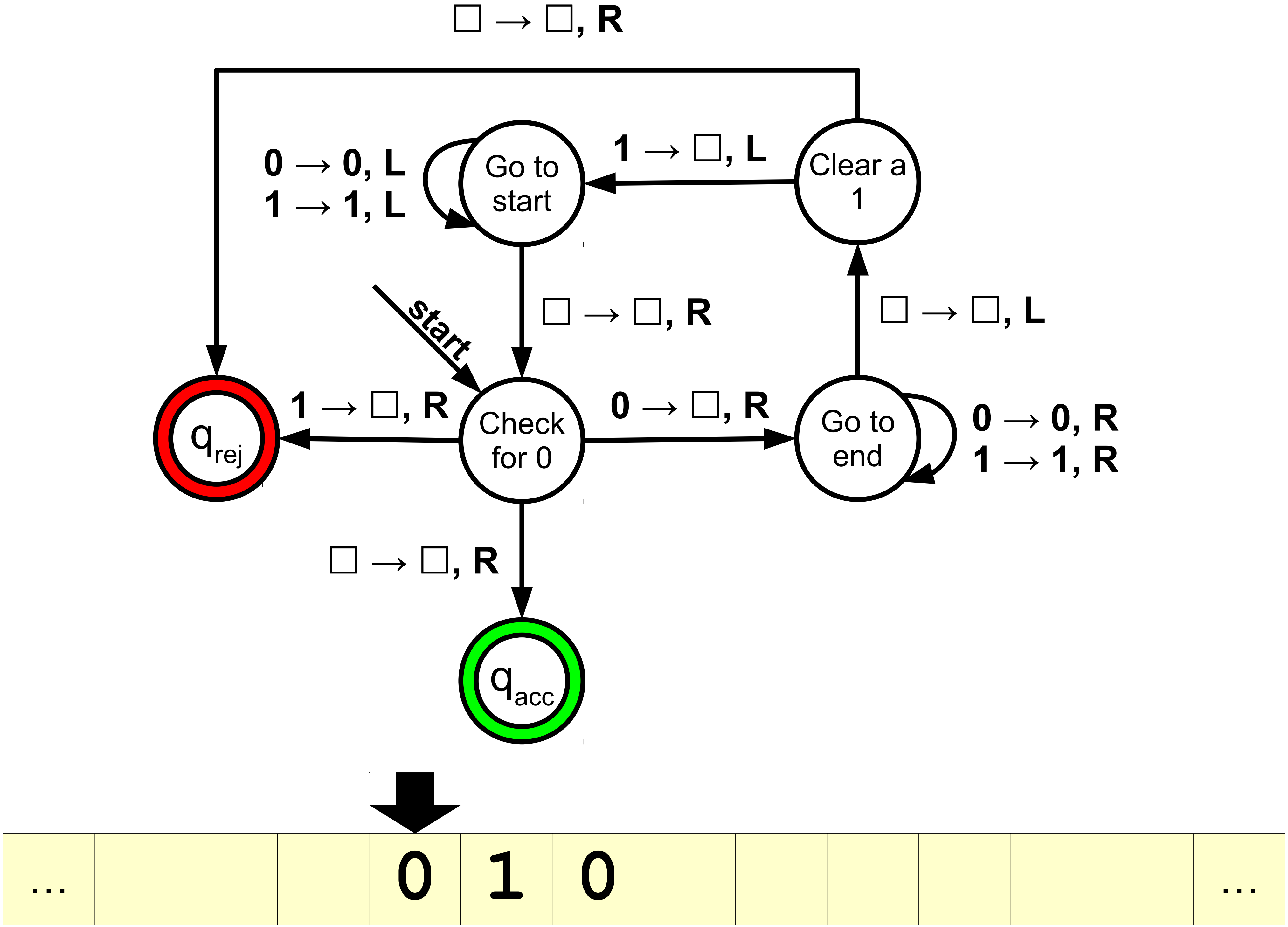

0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
□ → □, R
□ → □, L
start
1 → □, R
q_rej
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
…

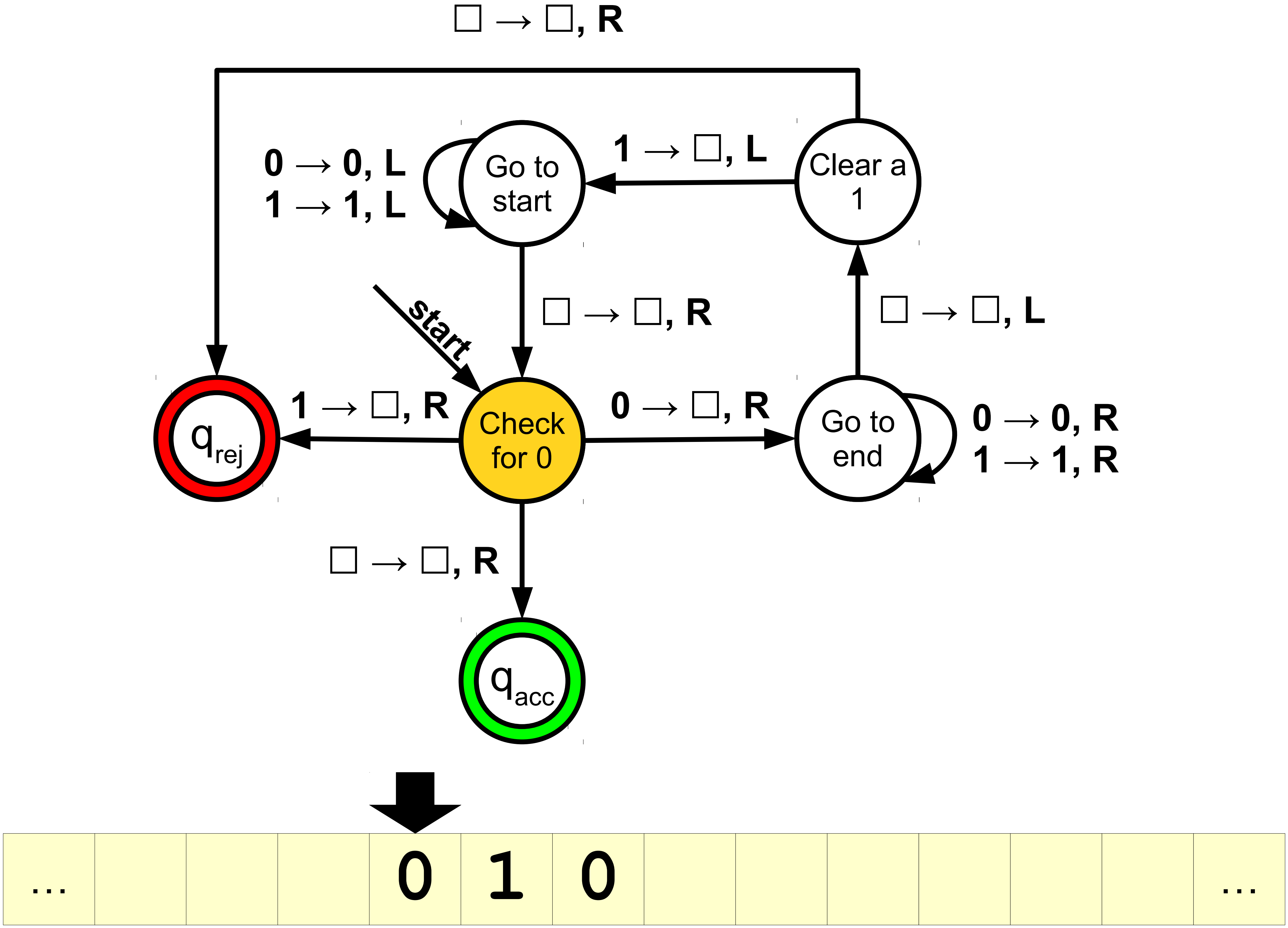

□ → □, R
0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
…

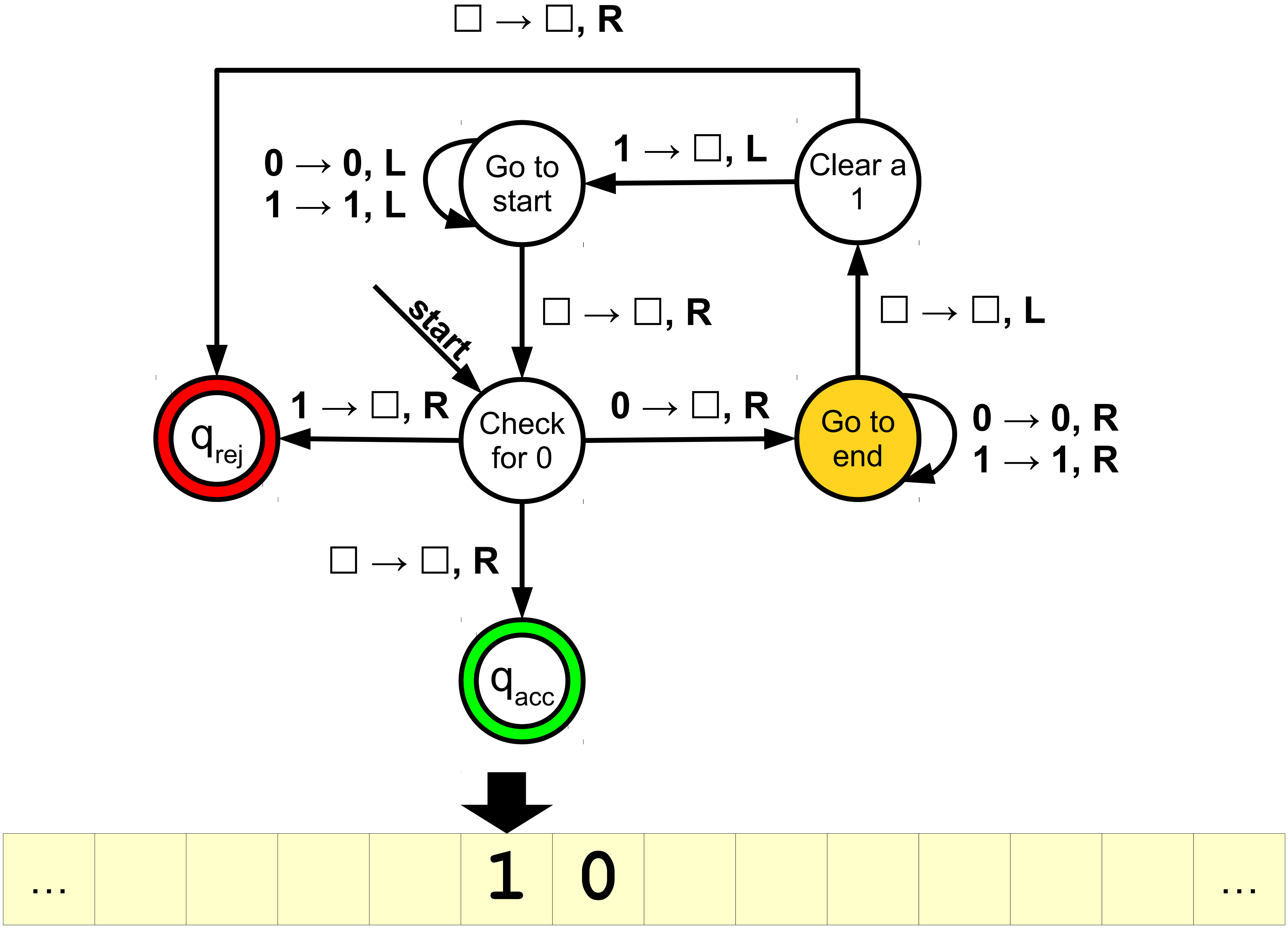

□ → □, R
0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
…

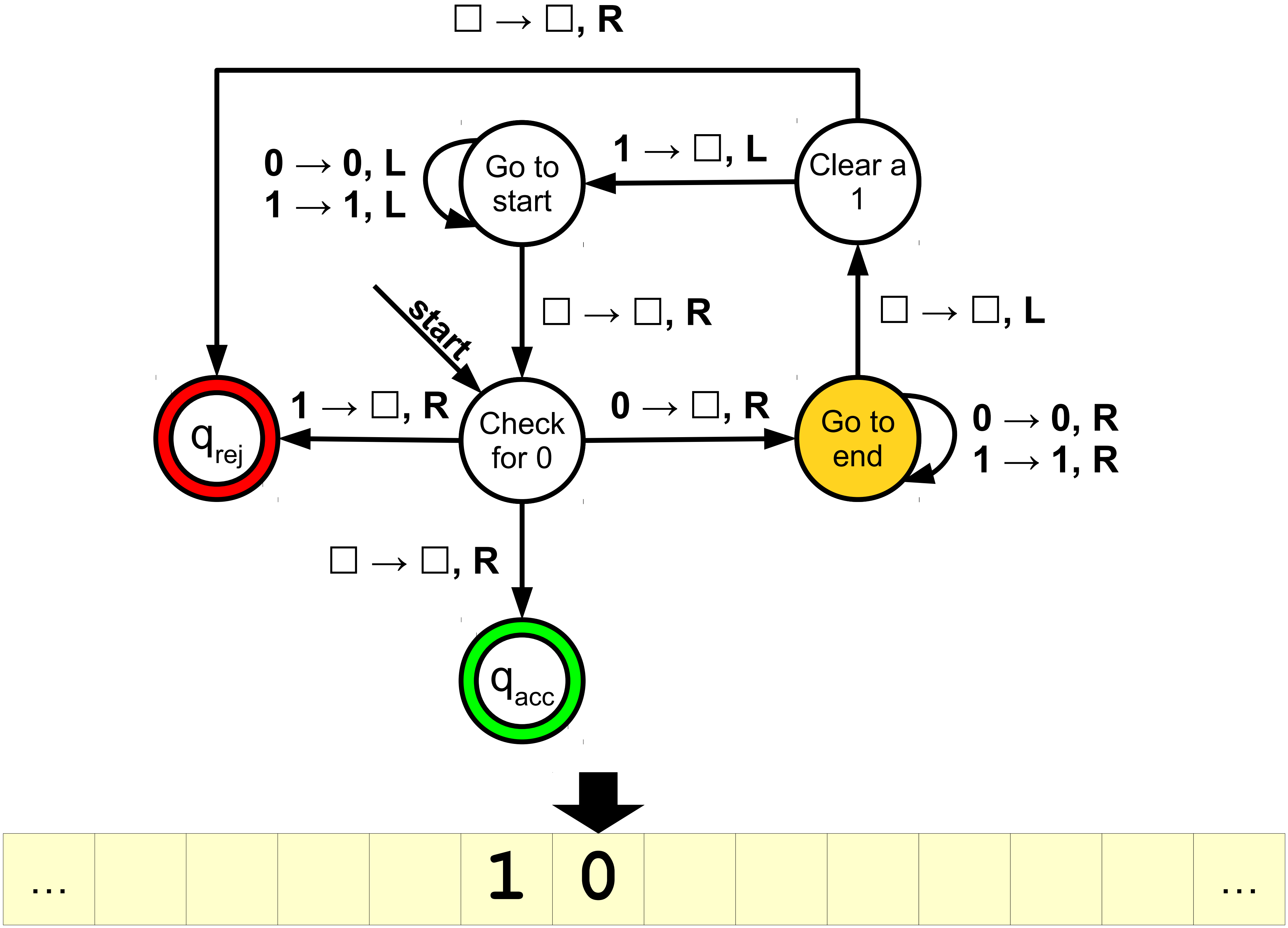

□ → □, R
Go to start
0 → 0, L
1 → 1, L
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
…

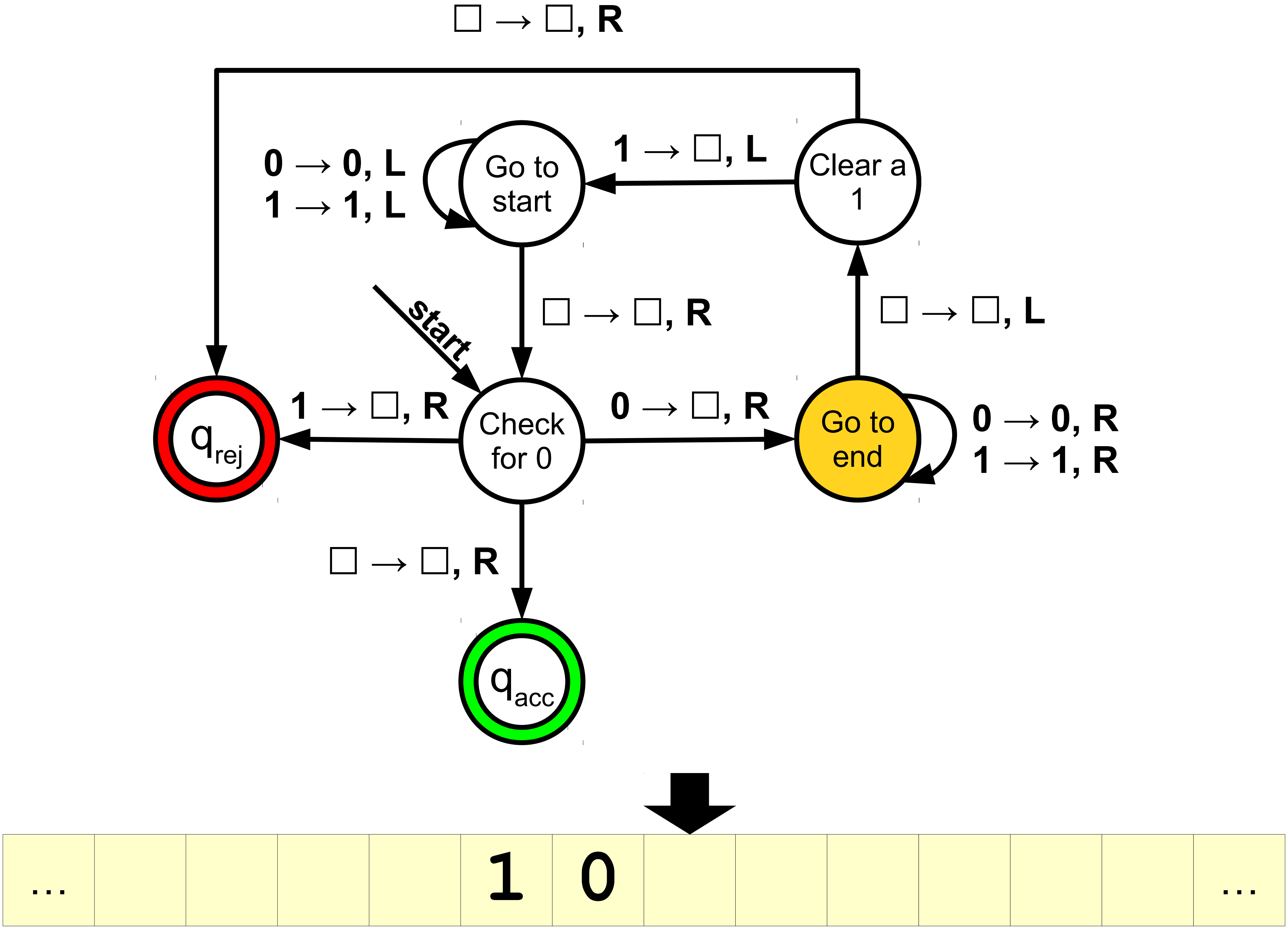

□ → □, R
0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc

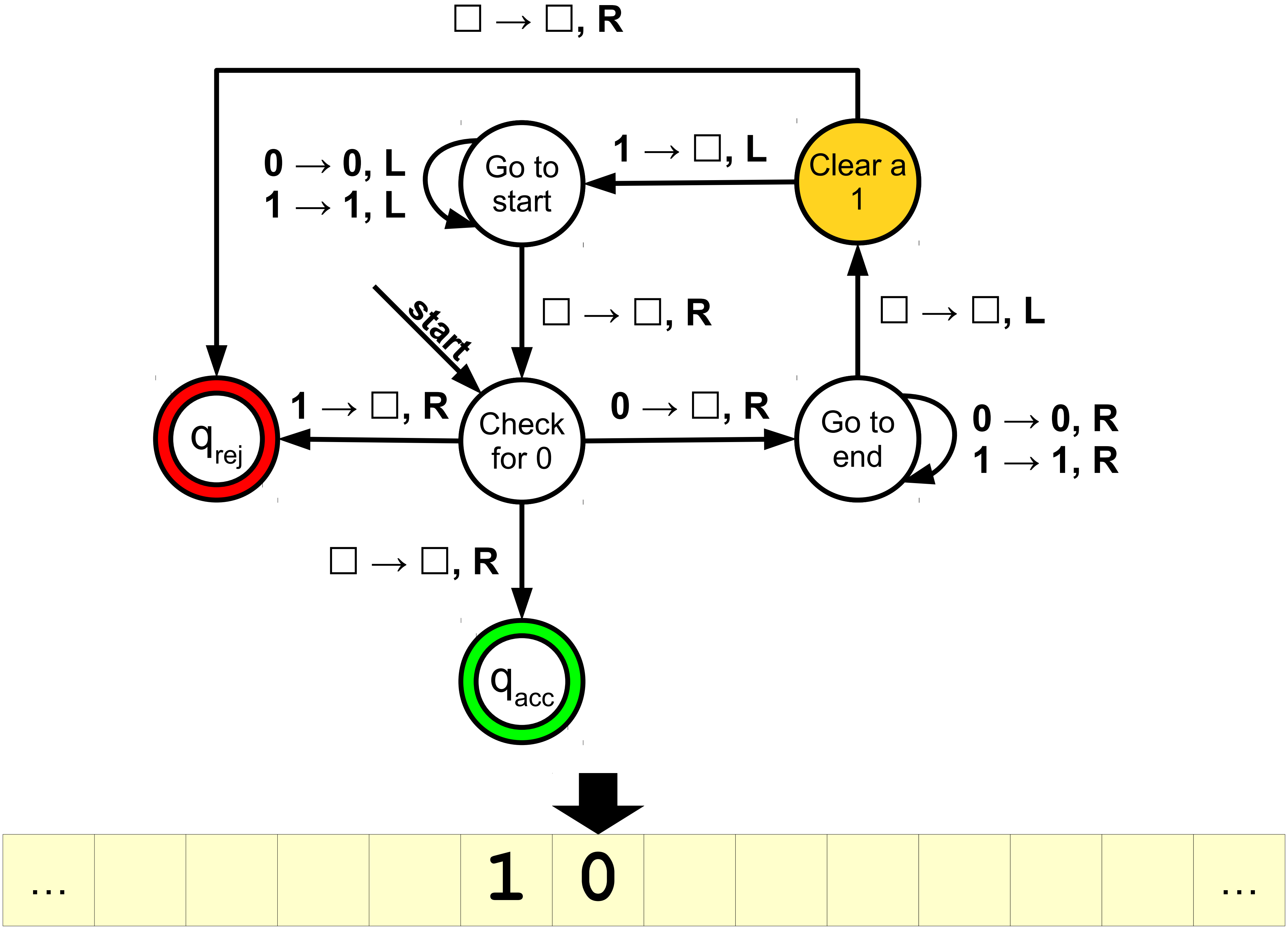

□ → □, R
0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
□ → □, R
□ → □, L
start
q_{rej}
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}
…
0
1
0
…

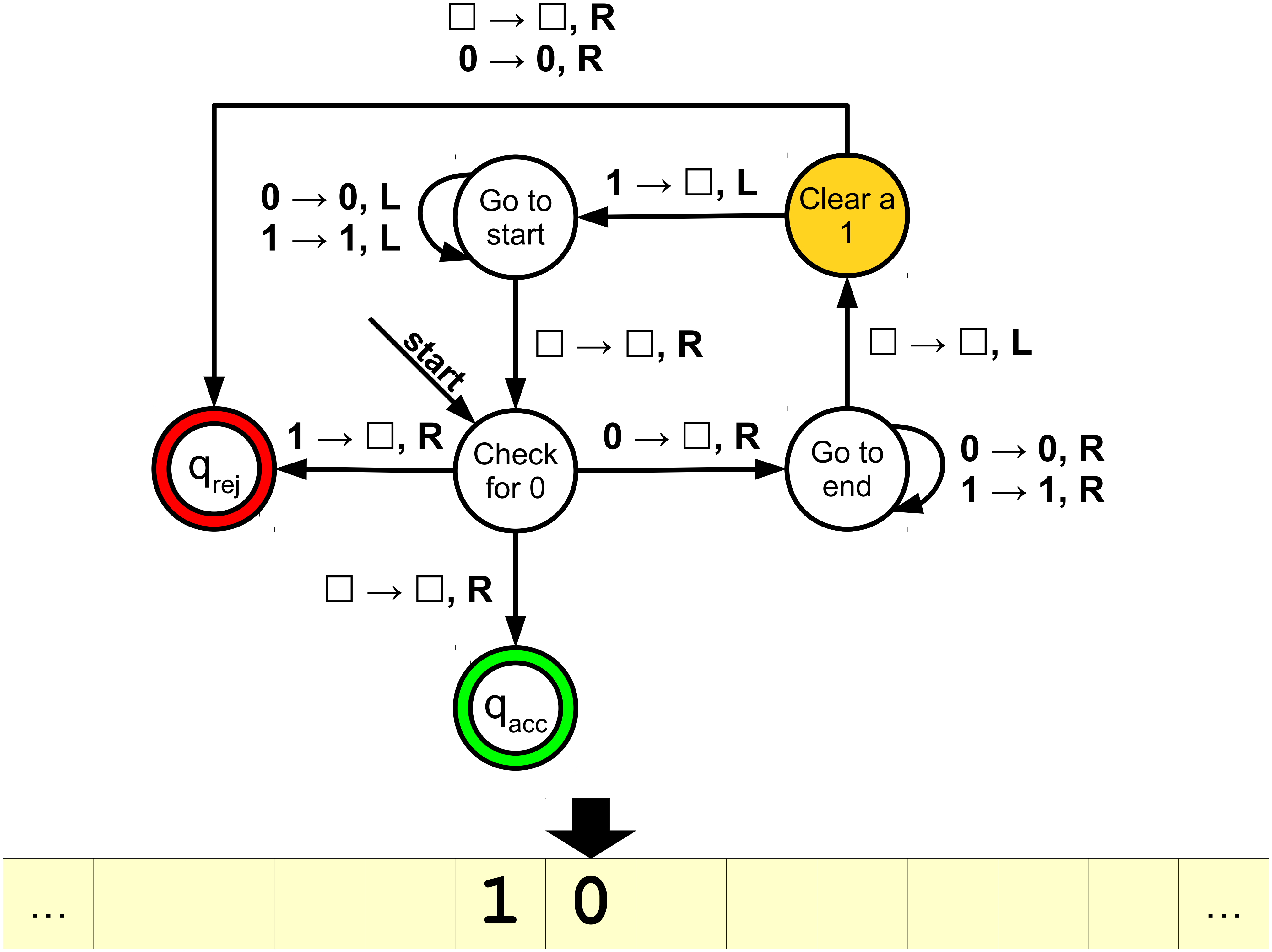

□ → □, R
0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
0
1
0
…

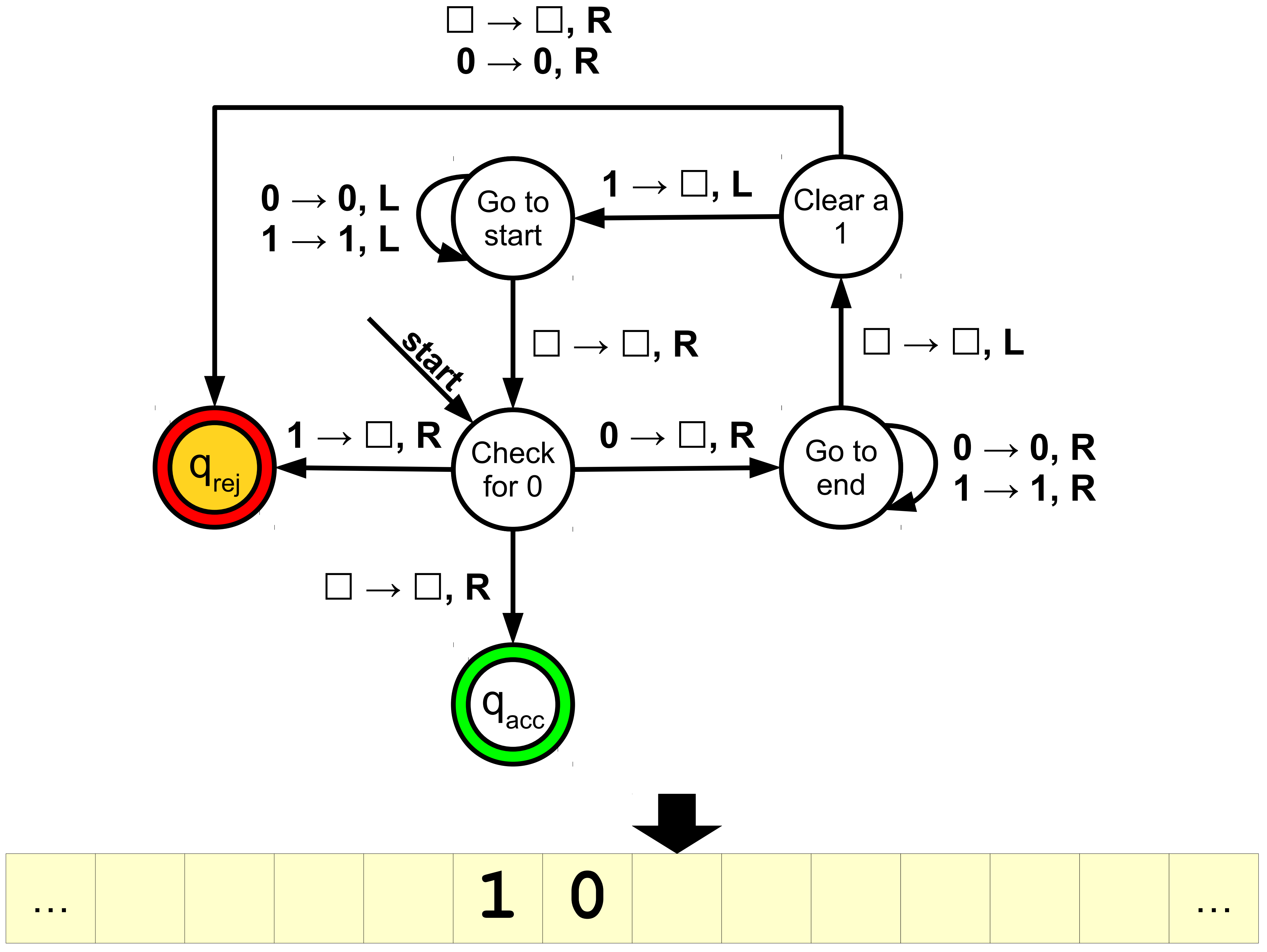

□ → □, R
0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
1
0
…

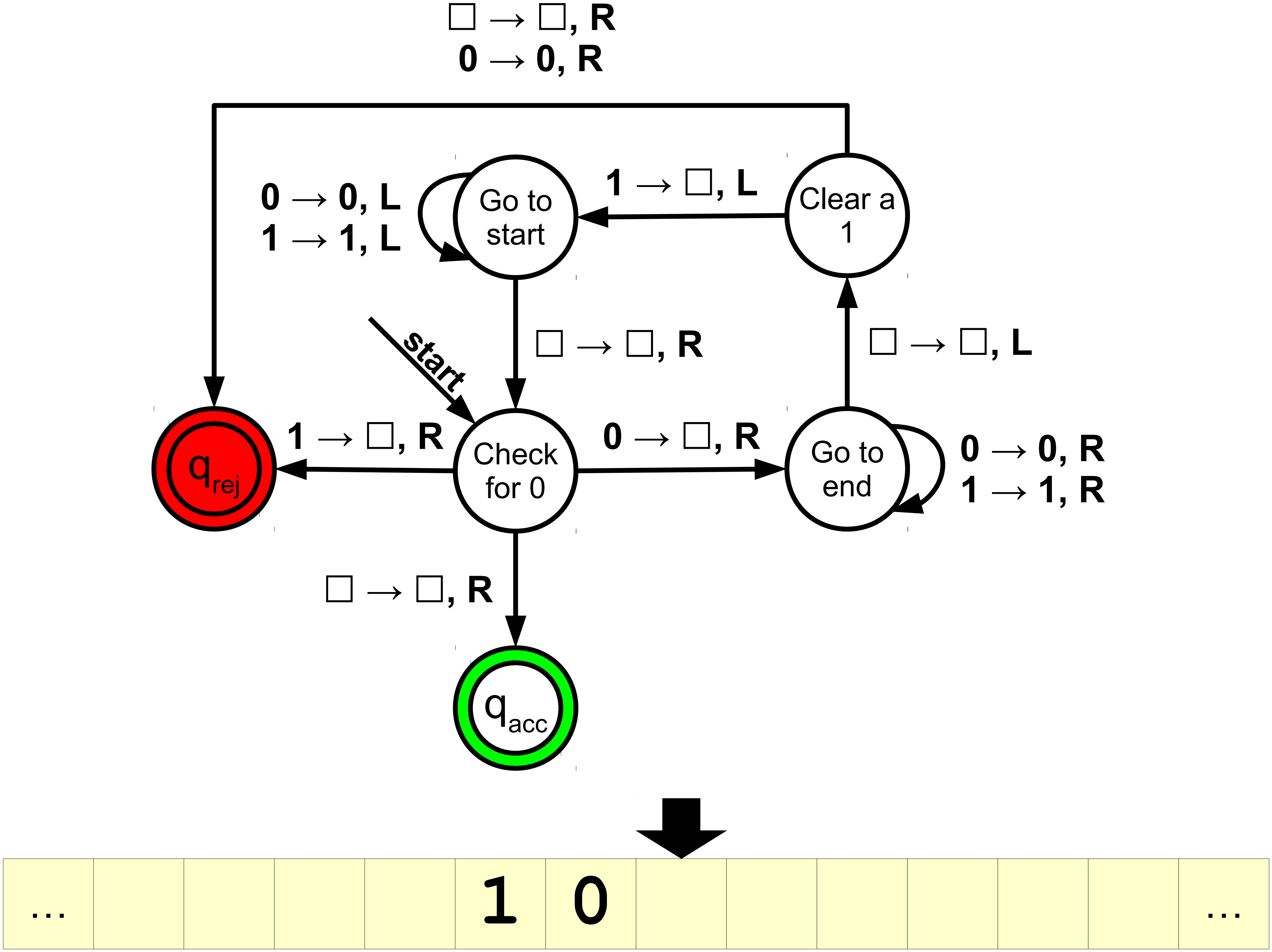

□ → □, R
0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
1
0
…

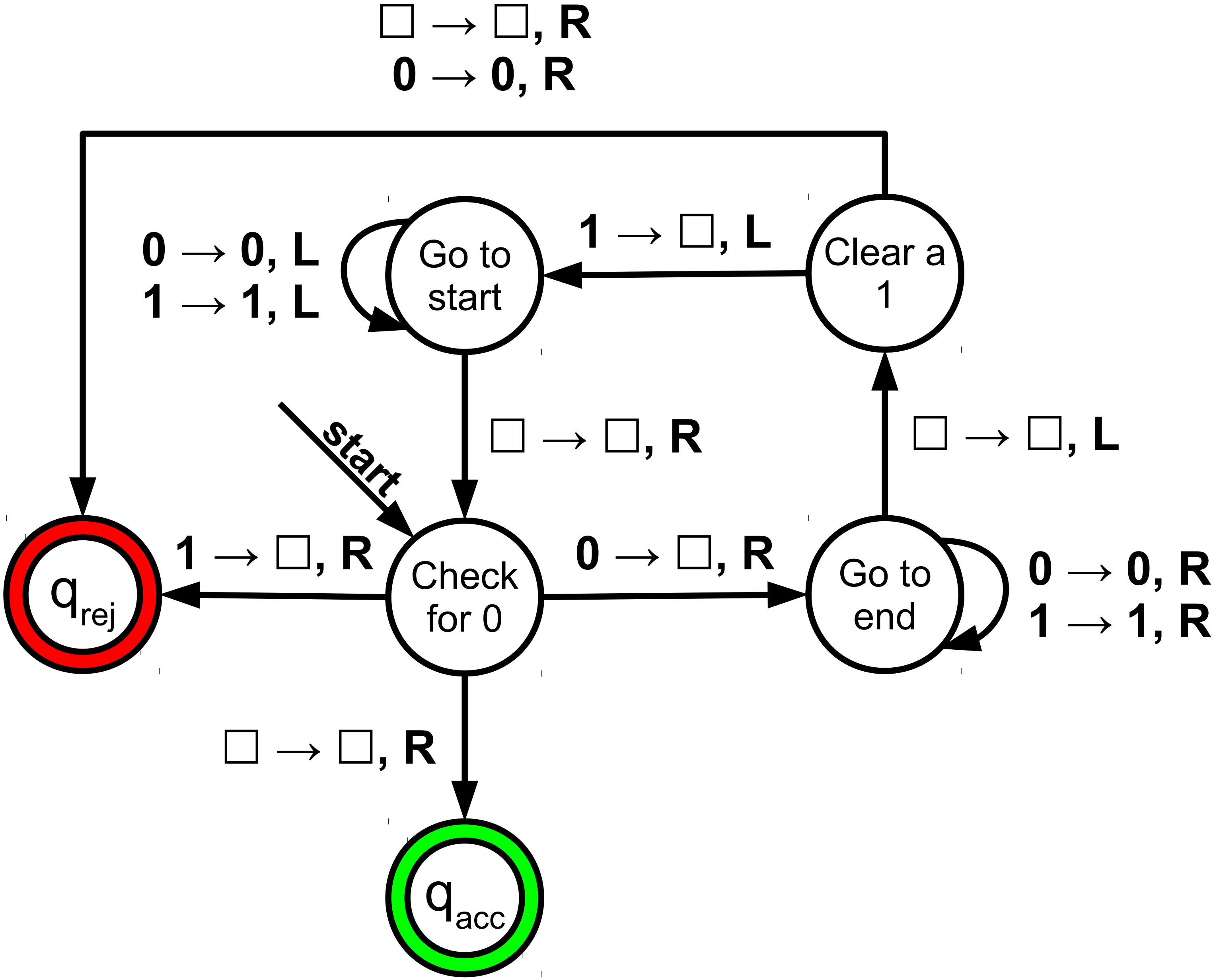

□ → □, R
0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
1
0
…


□ → □, R
1 → □, L
0 → 0, L
1 → 1, L
Go to start
Clear a 1
start
□ → □, R
□ → □, L
q_{rej}
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}
…
1
0
…


□ → □, R
0 → 0, R
0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
q_{rej}
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_{acc}
…
1
0
…


□ → □, R
0 → 0, R
0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
1
0
…


□ → □, R
0 → 0, R
0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc
…
1
0
…


□ → □, R
0 → 0, R
0 → 0, L
1 → 1, L
Go to start
1 → □, L
Clear a 1
start
□ → □, R
□ → □, L
q_rej
1 → □, R
Check for 0
0 → □, R
Go to end
0 → 0, R
1 → 1, R
□ → □, R
q_acc

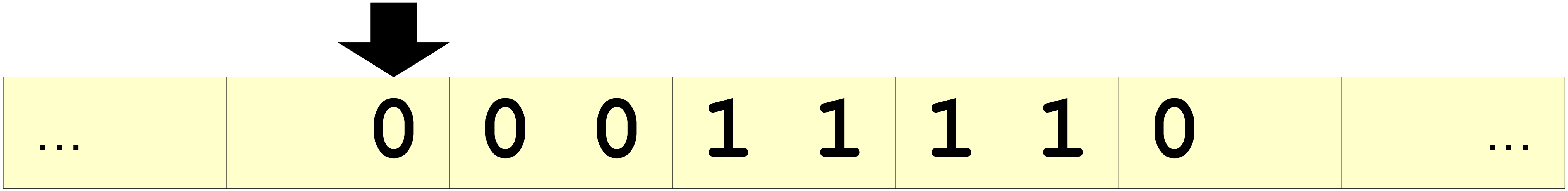
Another TM Design

- We've designed a TM for $\{\mathtt{0}^n\mathtt{1}^n \mid n \in \mathbb{N}\}$.
- Consider this language over $\Sigma = \{\mathtt{0}, \mathtt{1}\}$:

$$L = \{ w \in \Sigma^* \mid w \text{ has the same number of } \mathtt{0}\text{s and } \mathtt{1}\text{s} \}$$

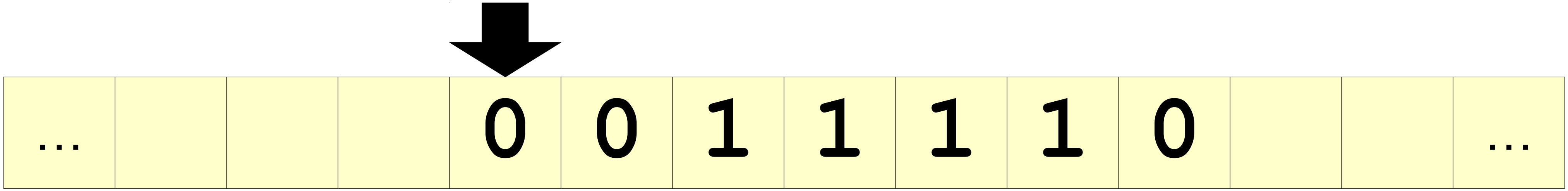
- This language is also not regular, but it is context-free.
- How might we design a TM for it?

A Caveat



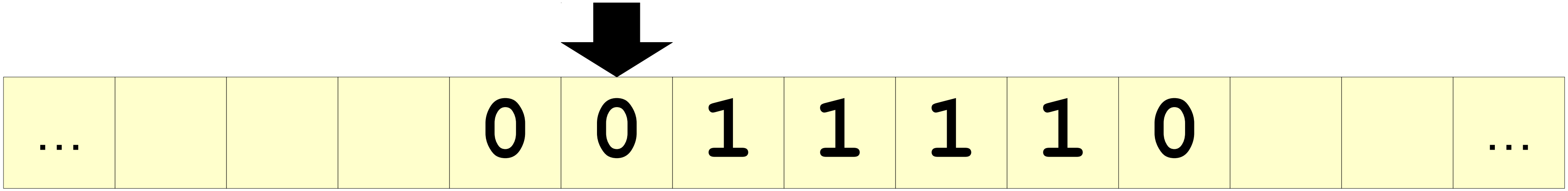
…			0	0	0	1	1	1	1	0			…

A Caveat

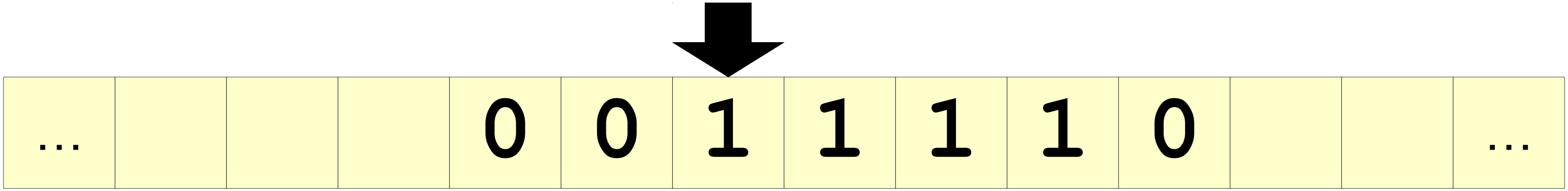


… 0 0 1 1 1 1 0 …

A Caveat

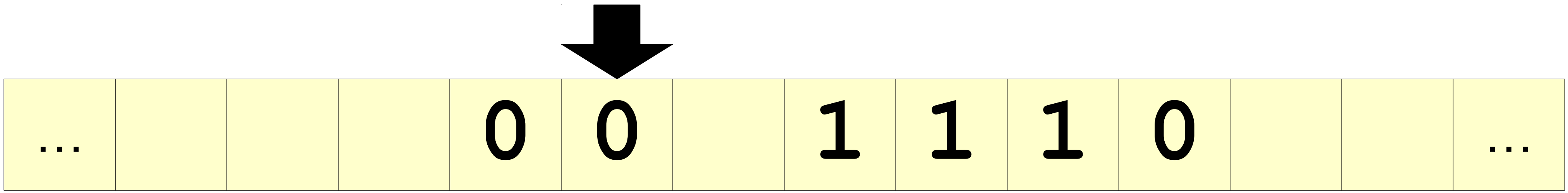


A Caveat

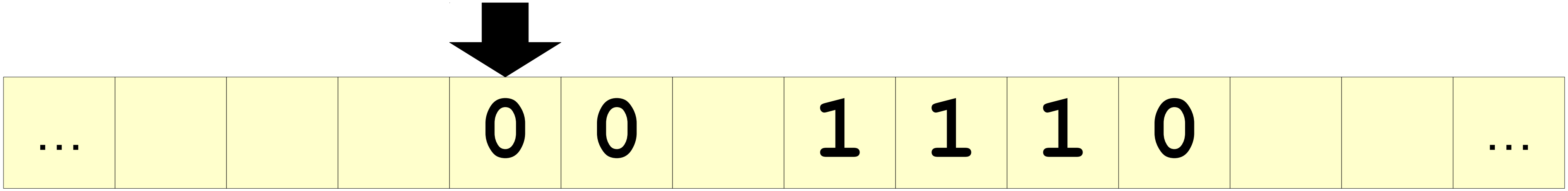


…				0	0	1	1	1	1	0			…

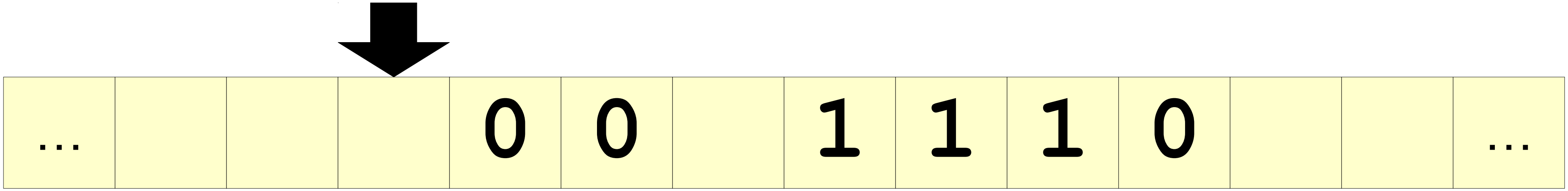
A Caveat



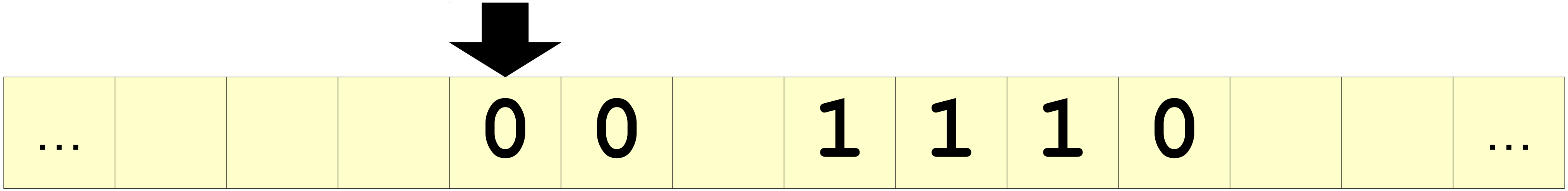
A Caveat



A Caveat

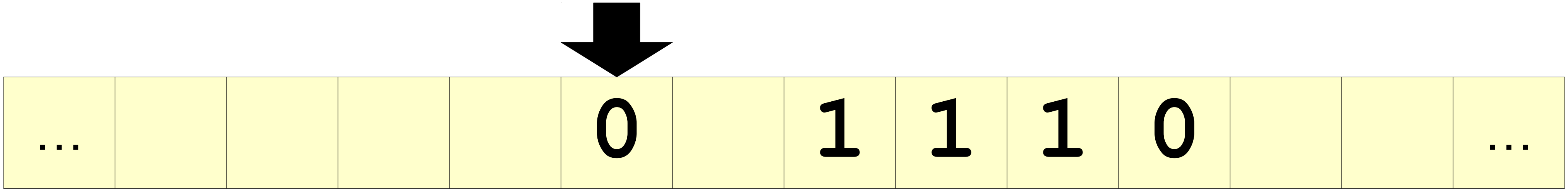


A Caveat



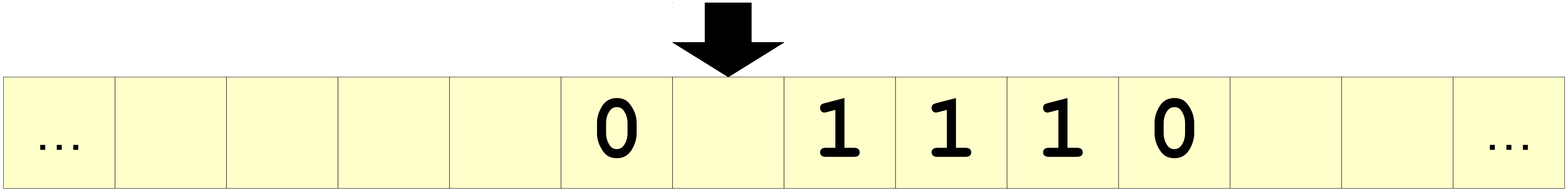
…				0	0		1	1	1	0			…

A Caveat

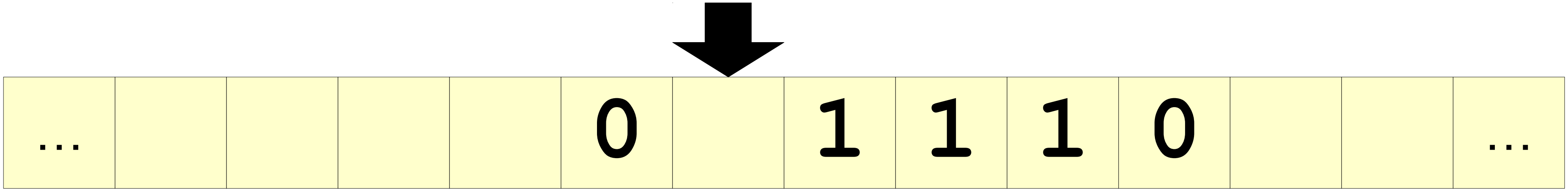


… 0 1 1 1 0 …

A Caveat

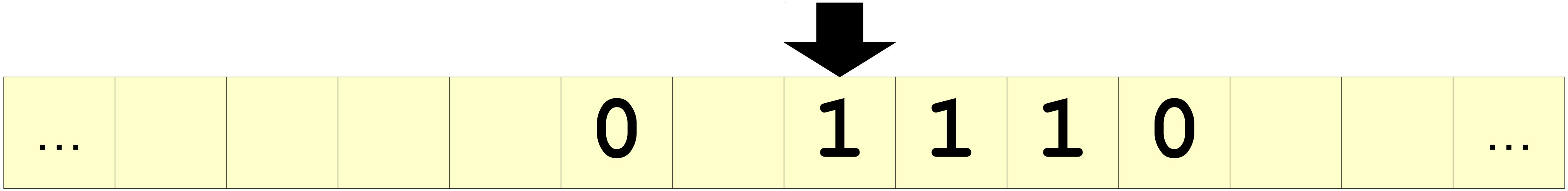


A Caveat



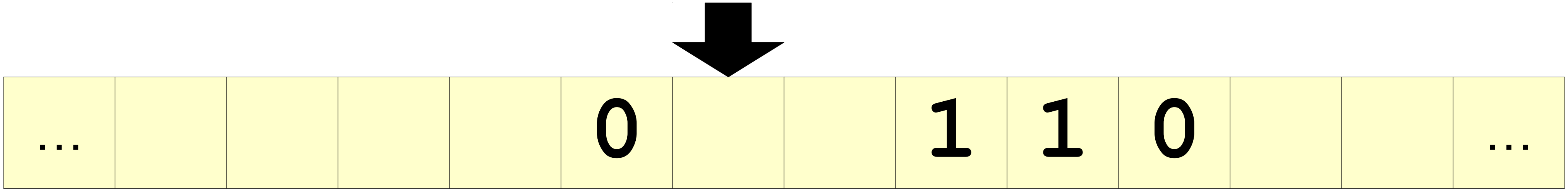
How do we know that this blank isn't one of the infinitely many blanks after our input string?

A Caveat

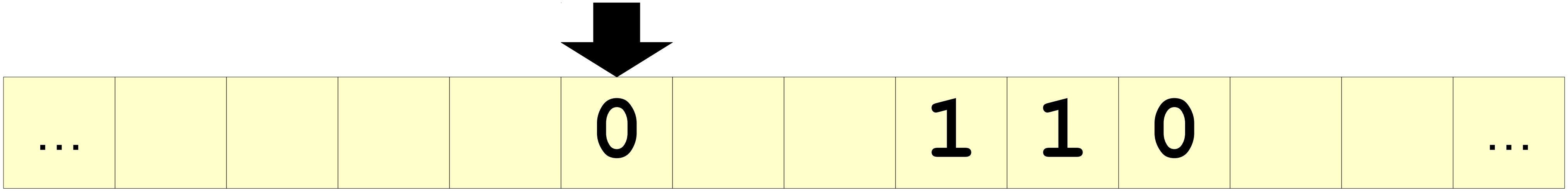


… 0 1 1 1 0 …

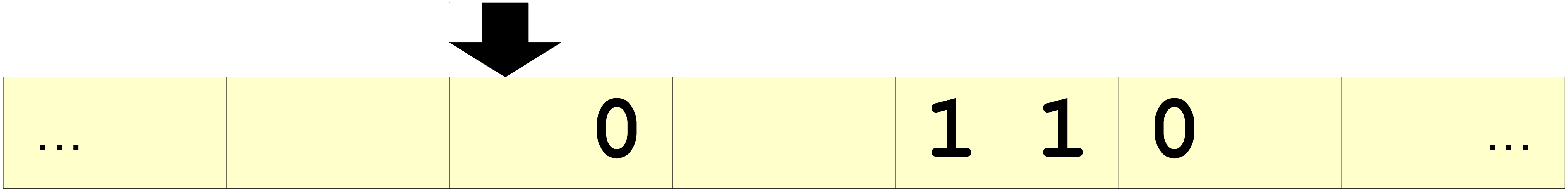
A Caveat



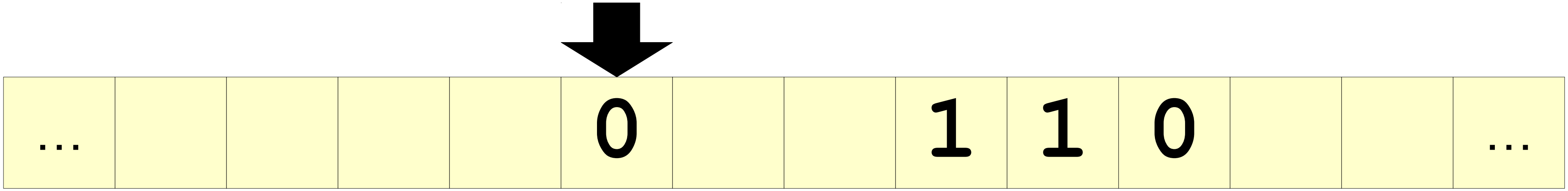
A Caveat



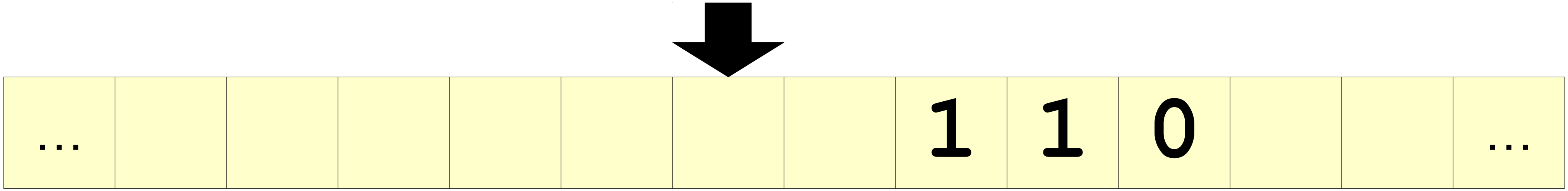
A Caveat



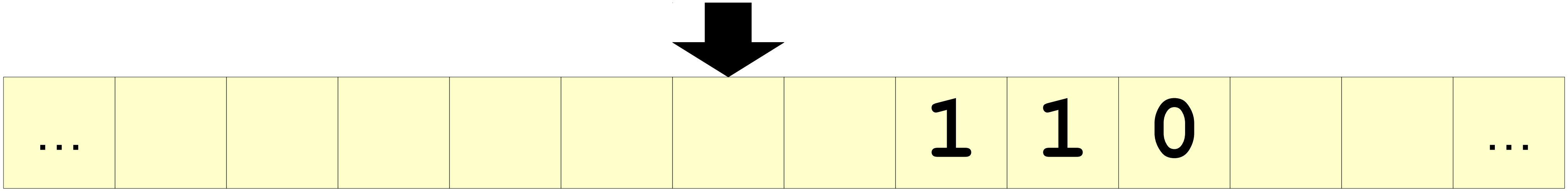
A Caveat



A Caveat

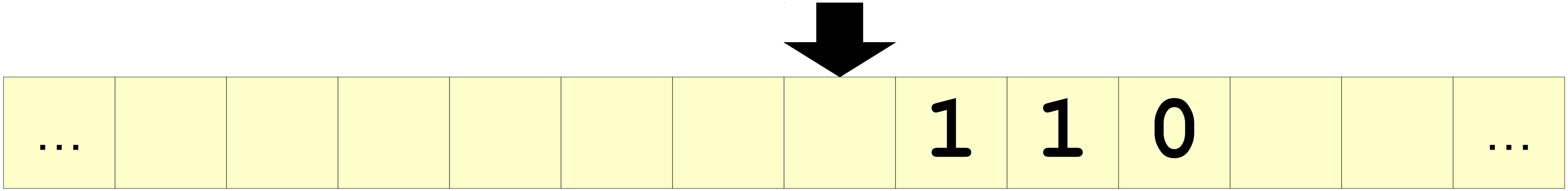


A Caveat

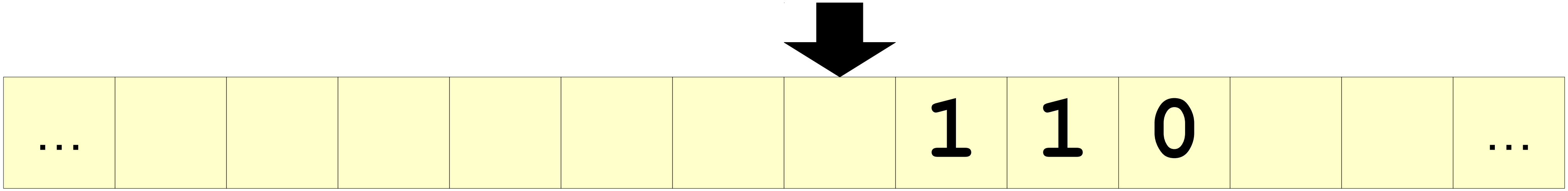


How do we know that this blank isn't one of the infinitely many blanks after our input string?

A Caveat

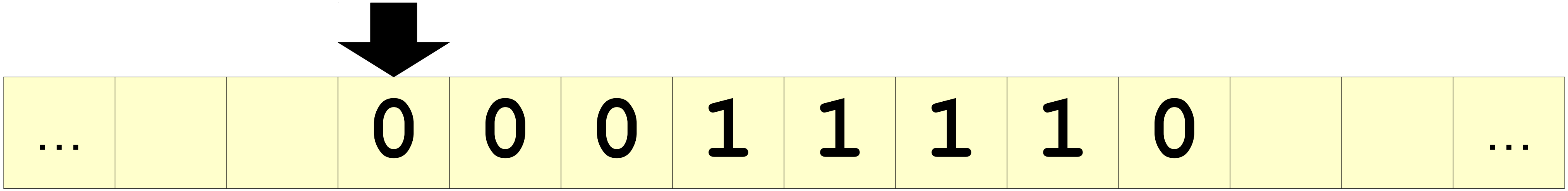


A Caveat



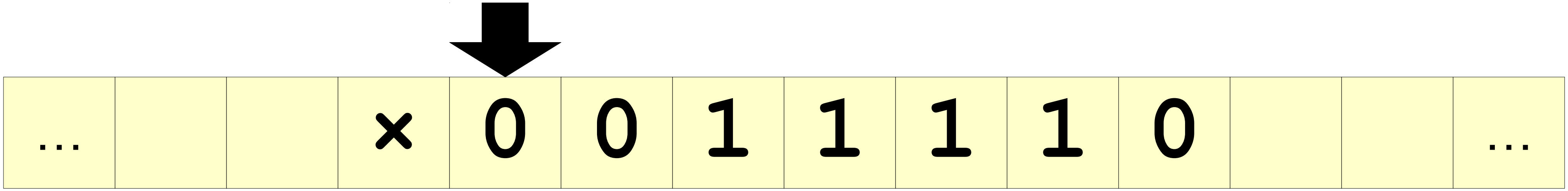
How do we know that this blank isn't one of the infinitely many blanks after our input string?

The Solution



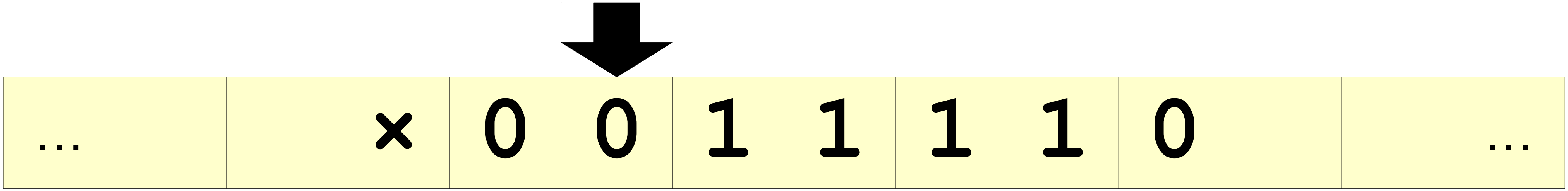
…			0	0	0	1	1	1	1	0			…

The Solution

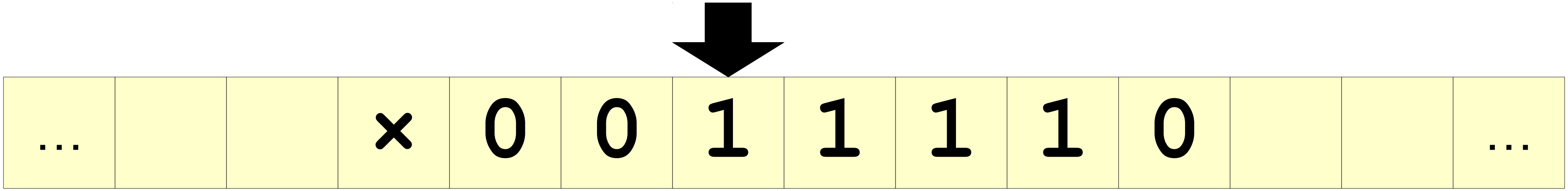


…			×	0	0	1	1	1	1	0			…

The Solution

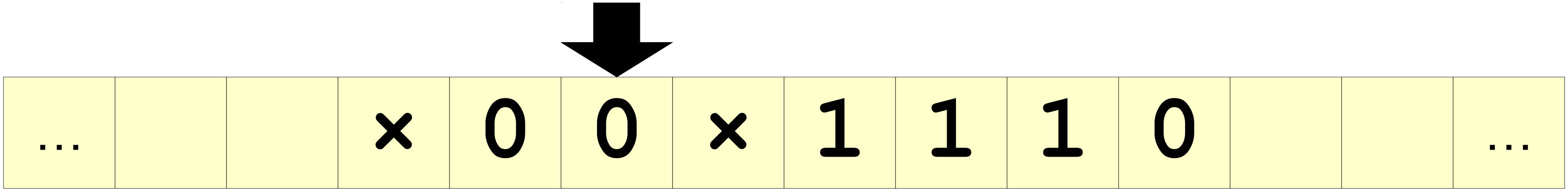


The Solution

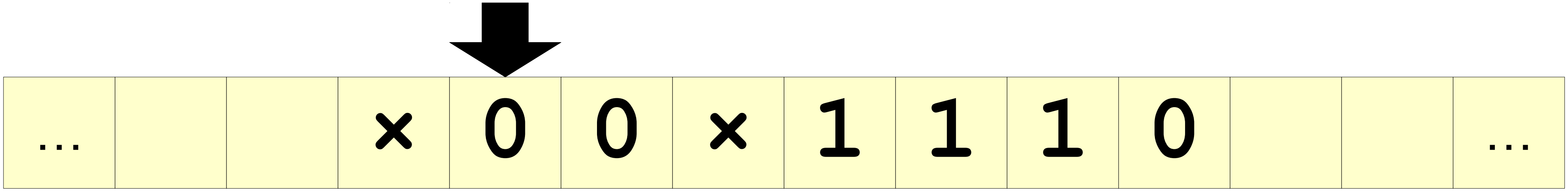


… × 0 0 1 1 1 1 0 …

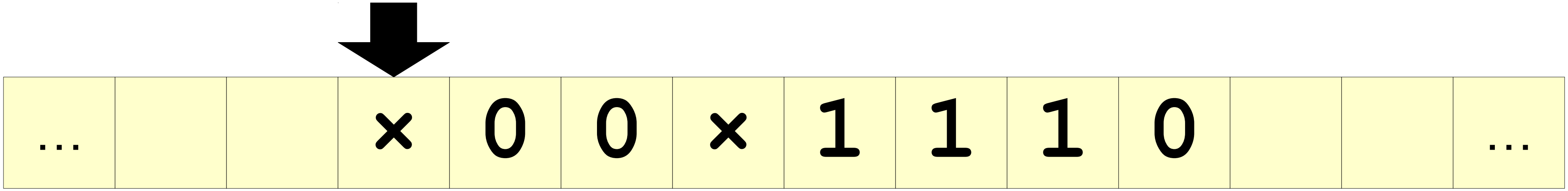
The Solution



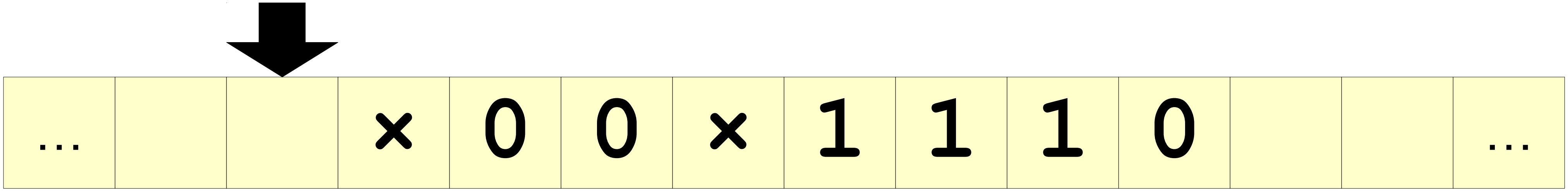
The Solution



The Solution

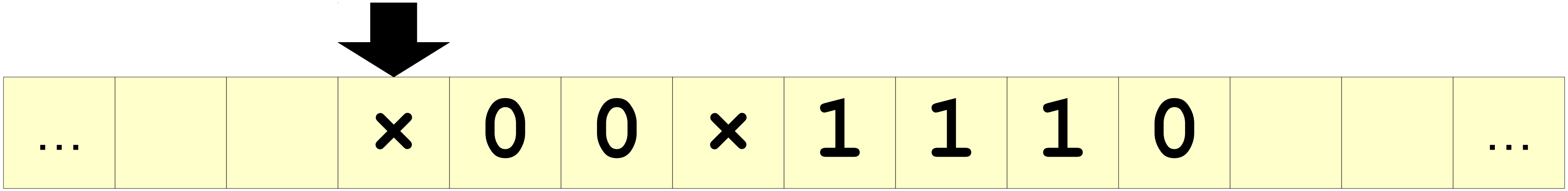


The Solution



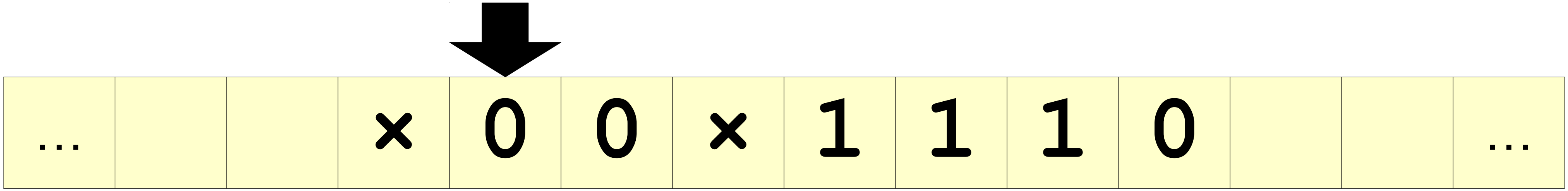
…			×	0	0	×	1	1	1	0			…

The Solution



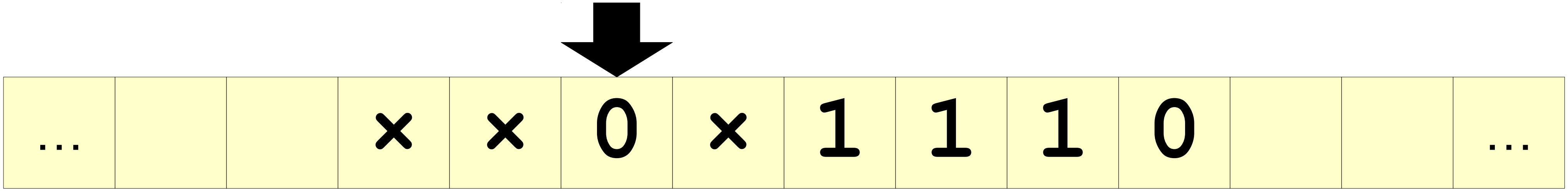
…			×	0	0	×	1	1	1	0			…

The Solution



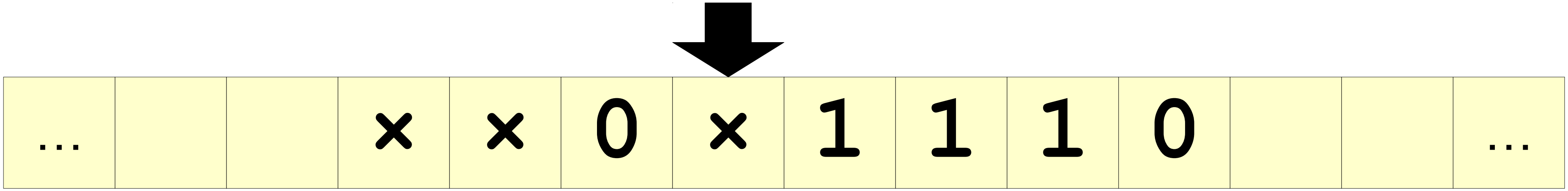
… × 0 0 × 1 1 1 0 …

The Solution



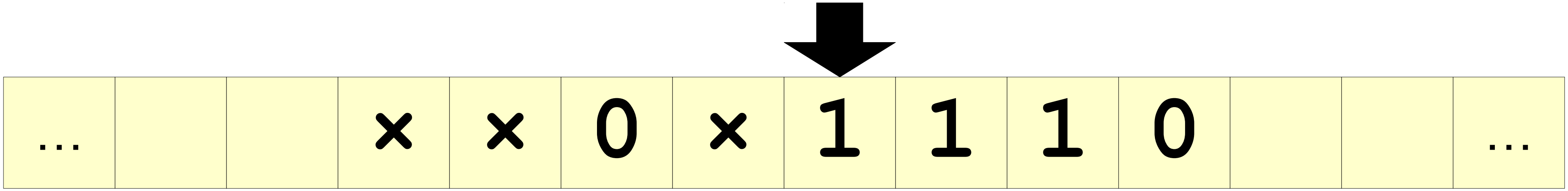
…			×	×	0	×	1	1	1	0			…

The Solution



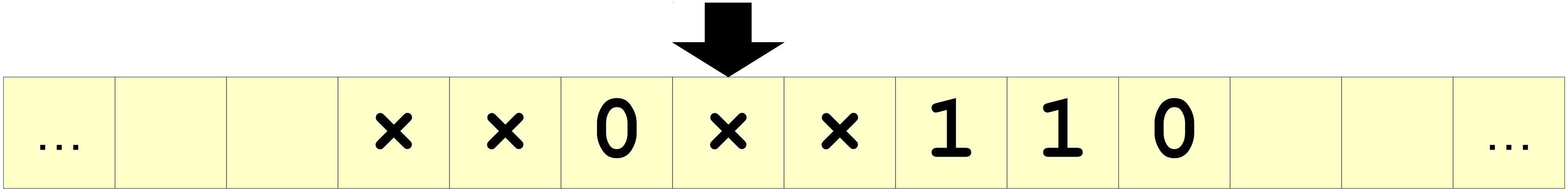
…			×	×	0	×	1	1	1	0			…

The Solution



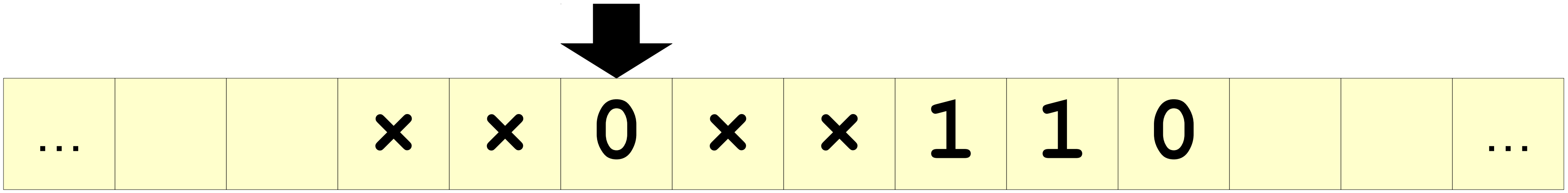
…			×	×	0	×	1	1	1	0			…

The Solution

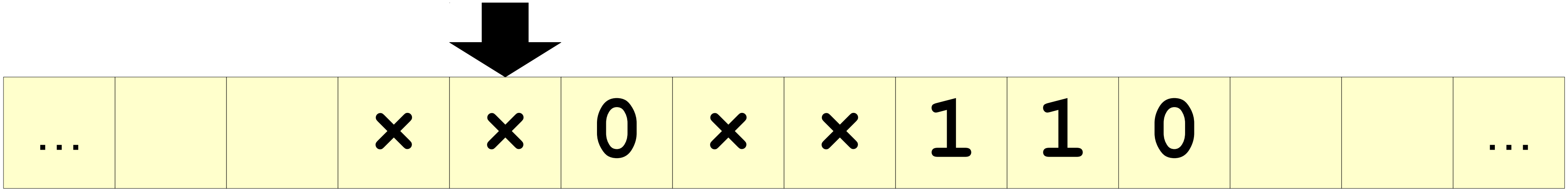


…			×	×	0	×	×	1	1	0			…

The Solution

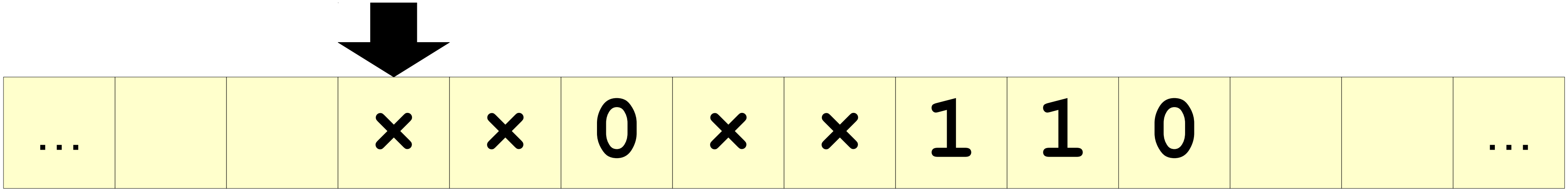


The Solution



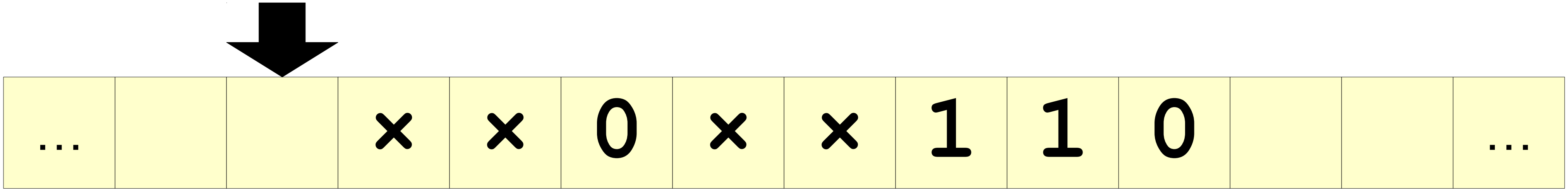
…			×	×	0	×	×	1	1	0			…

The Solution



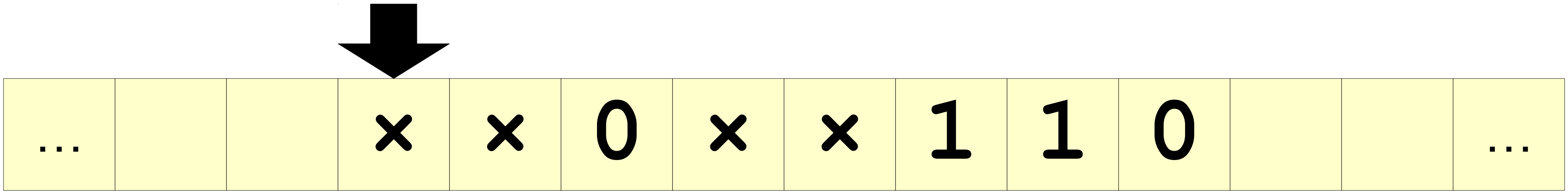
…			×	×	0	×	×	1	1	0			…

The Solution



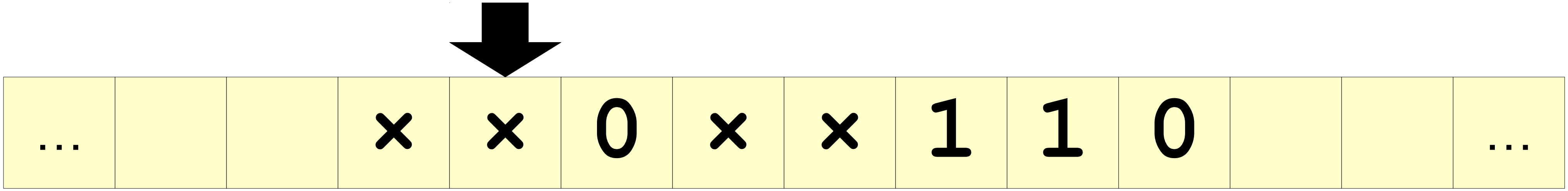
…			×	×	0	×	×	1	1	0			…

The Solution



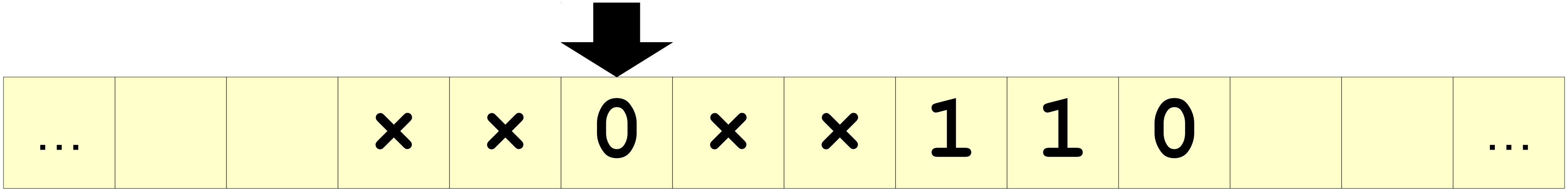
…			×	×	0	×	×	1	1	0			…

The Solution



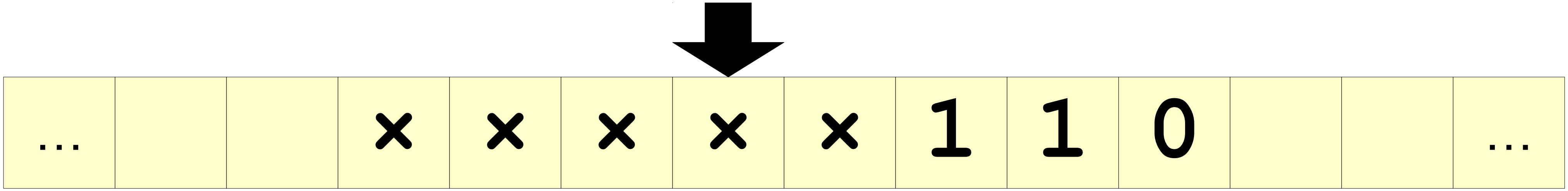
…			×	×	0	×	×	1	1	0			…

The Solution



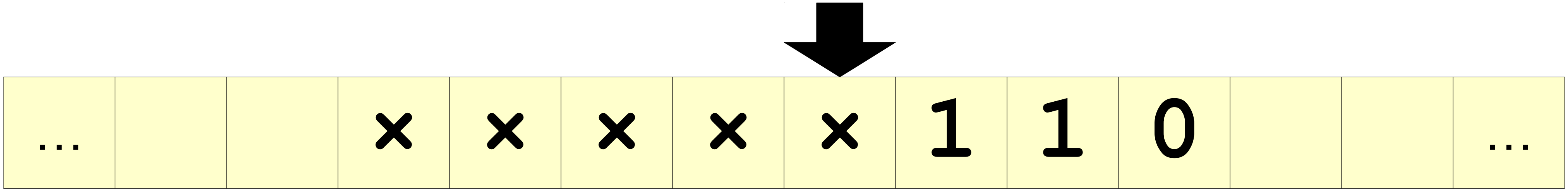
…			×	×	0	×	×	1	1	0			…

The Solution

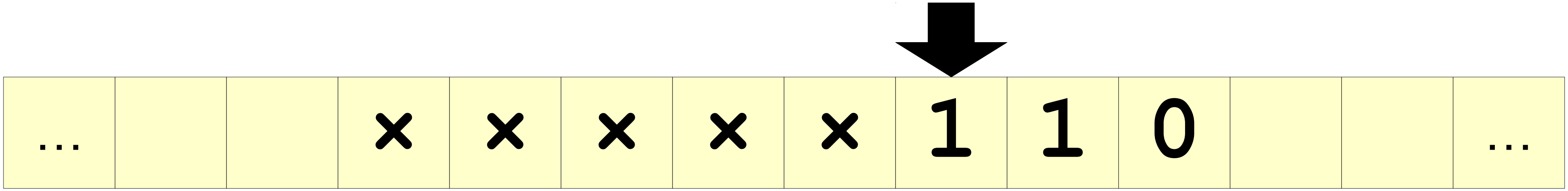


…			×	×	×	×	×	1	1	0			…

The Solution

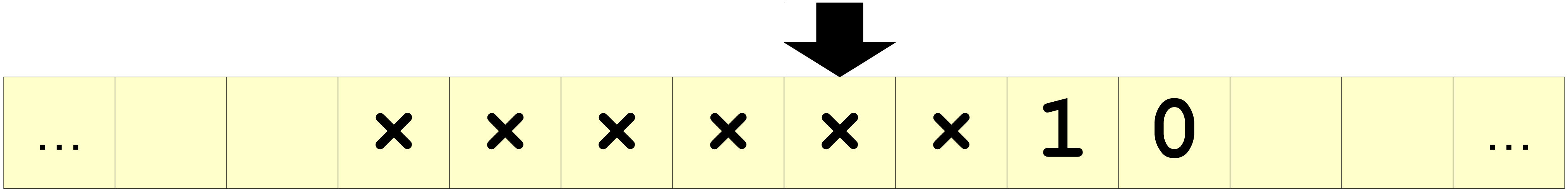


The Solution



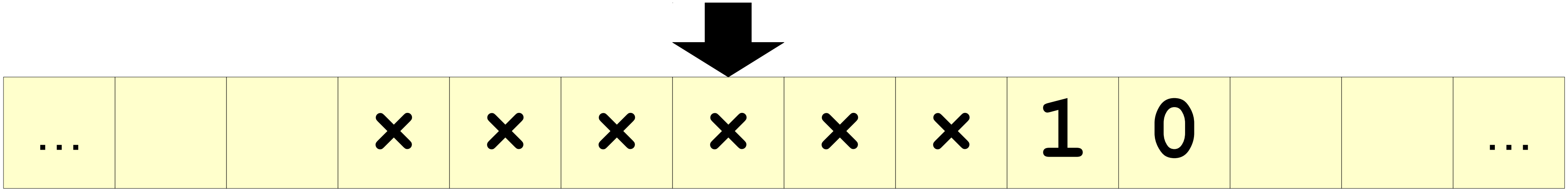
…			×	×	×	×	×	1	1	0			…

The Solution

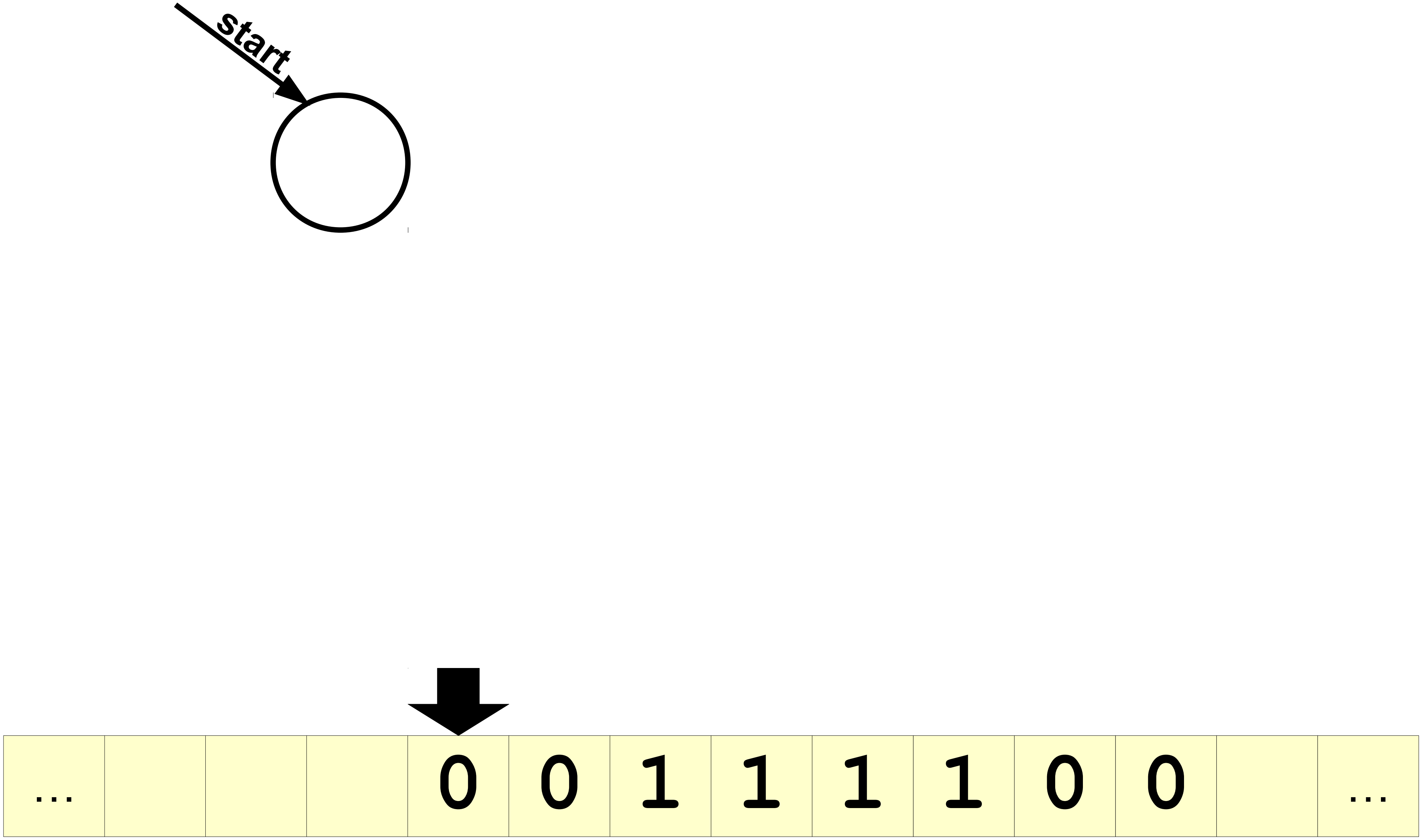


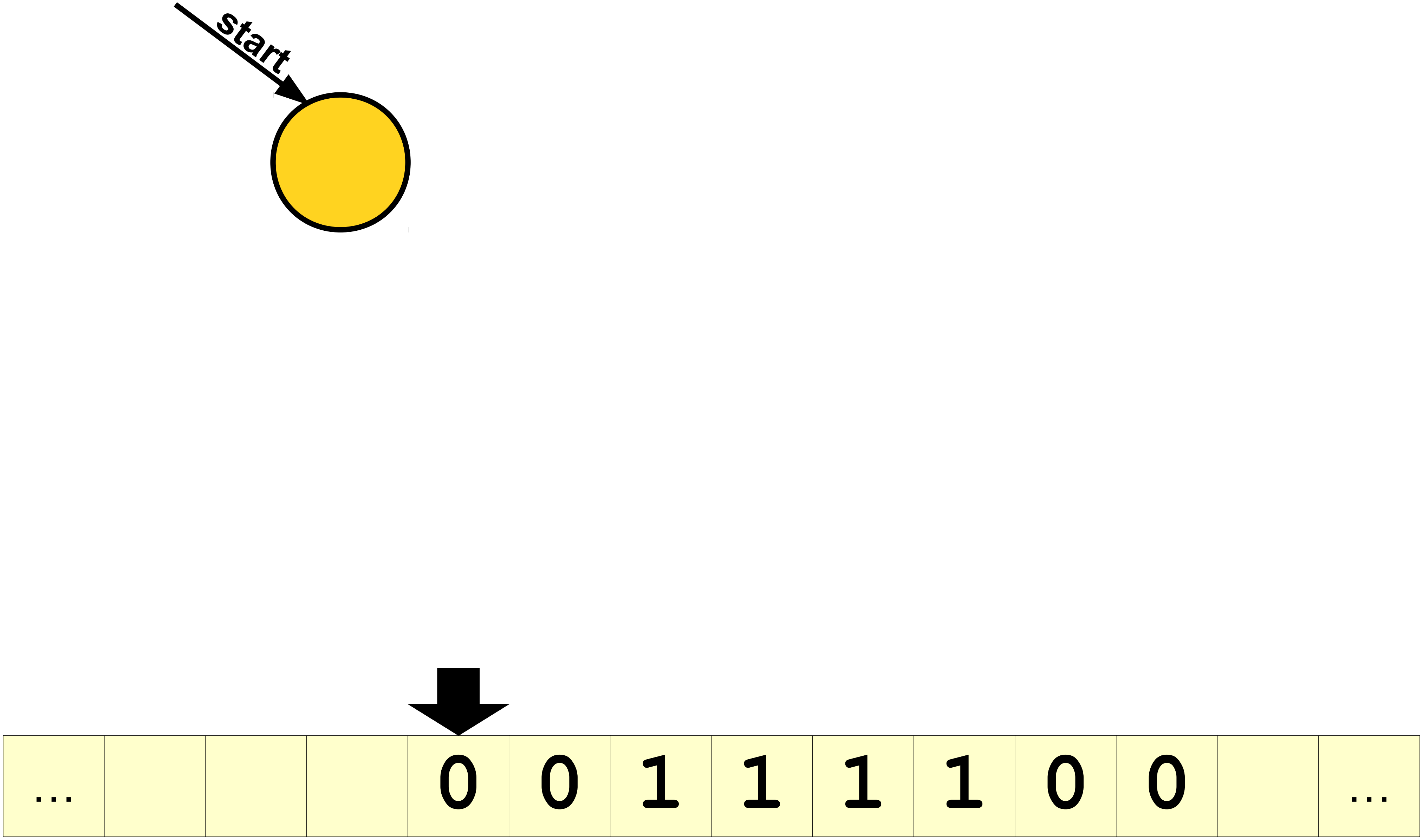
…			×	×	×	×	×	×	1	0			…

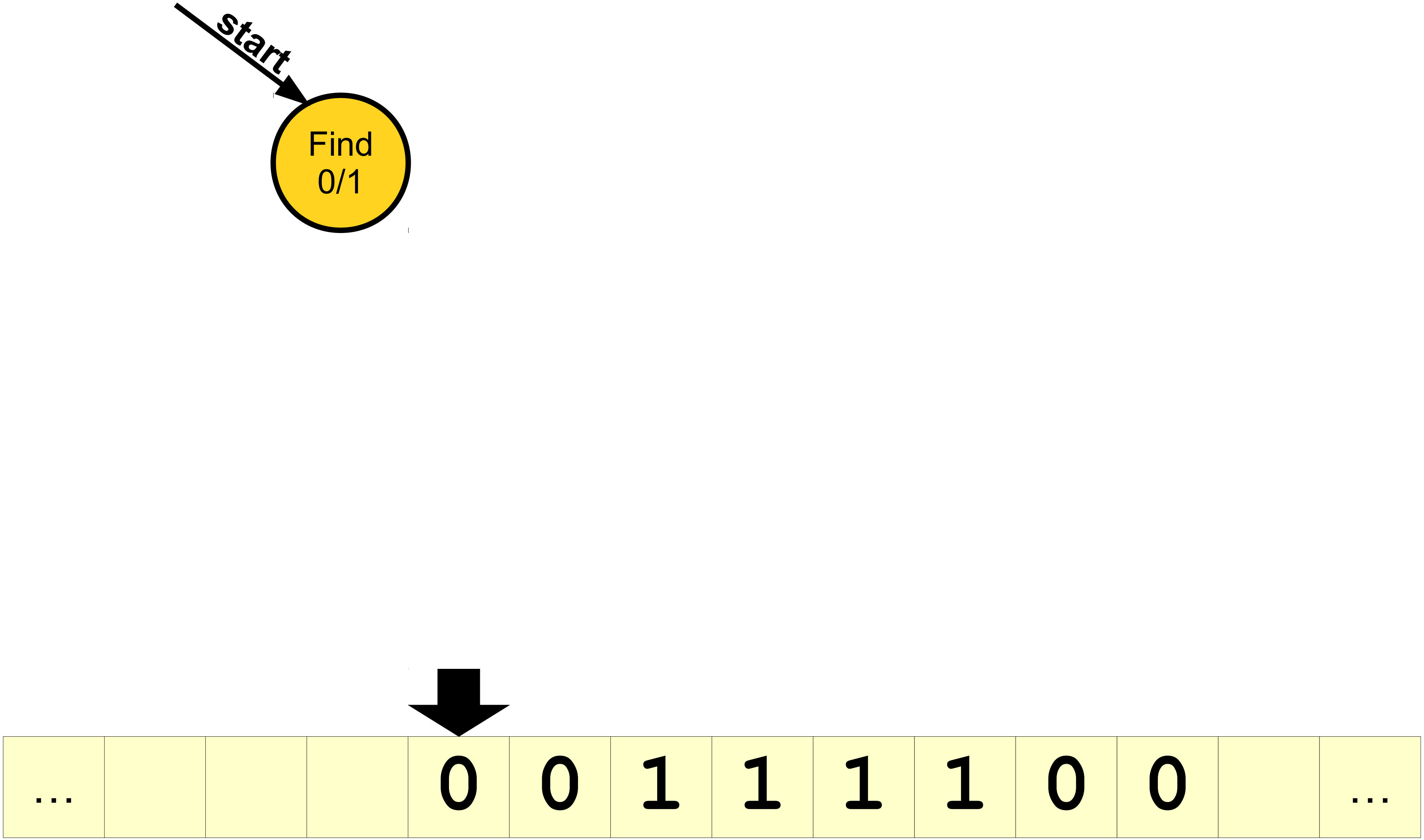
The Solution

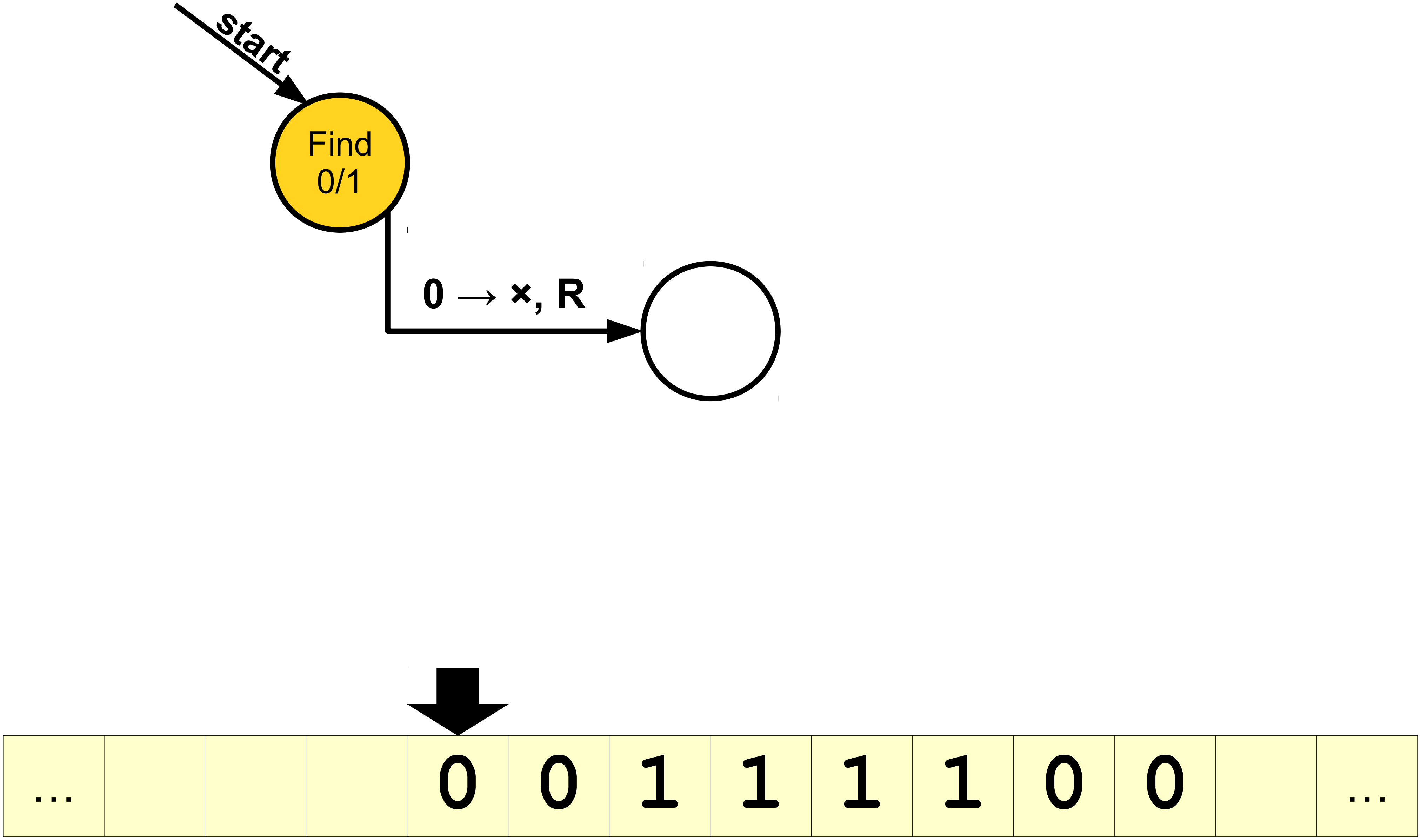


…			×	×	×	×	×	×	1	0			…

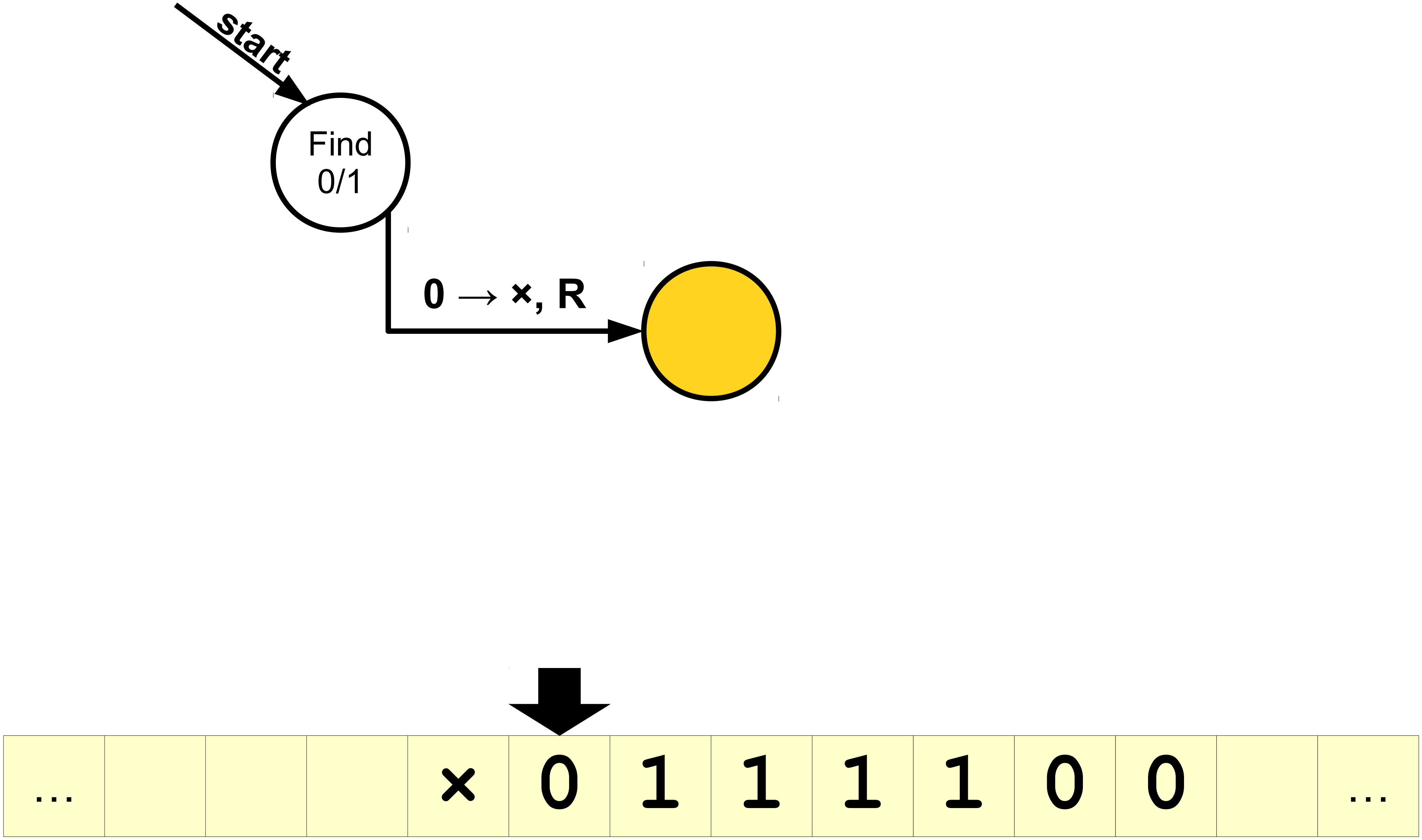

start
…
0
0
1
1
1
1
0
0
…

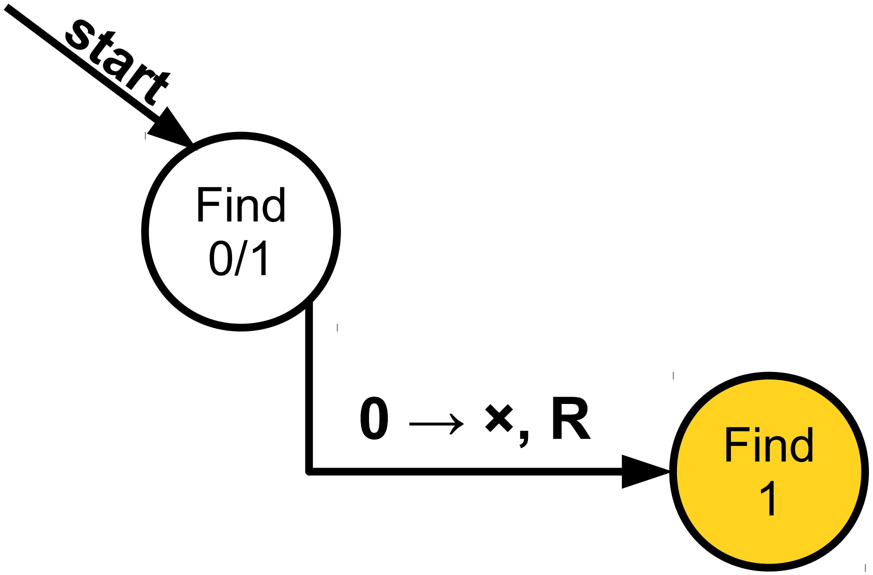

start
…
0
0
1
1
1
1
0
0
…

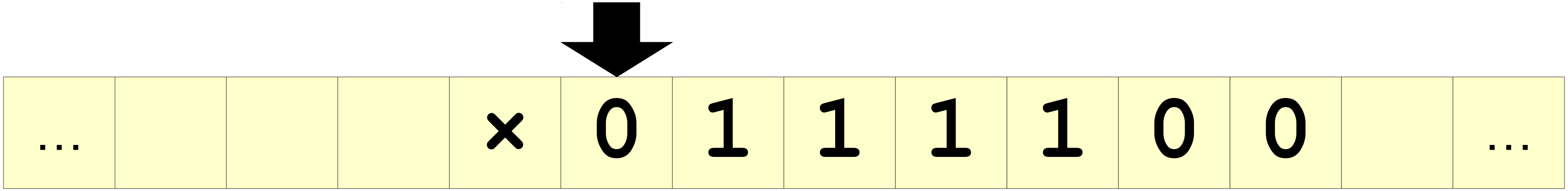

start
Find
0/1
…
0
0
1
1
1
1
0
0
…



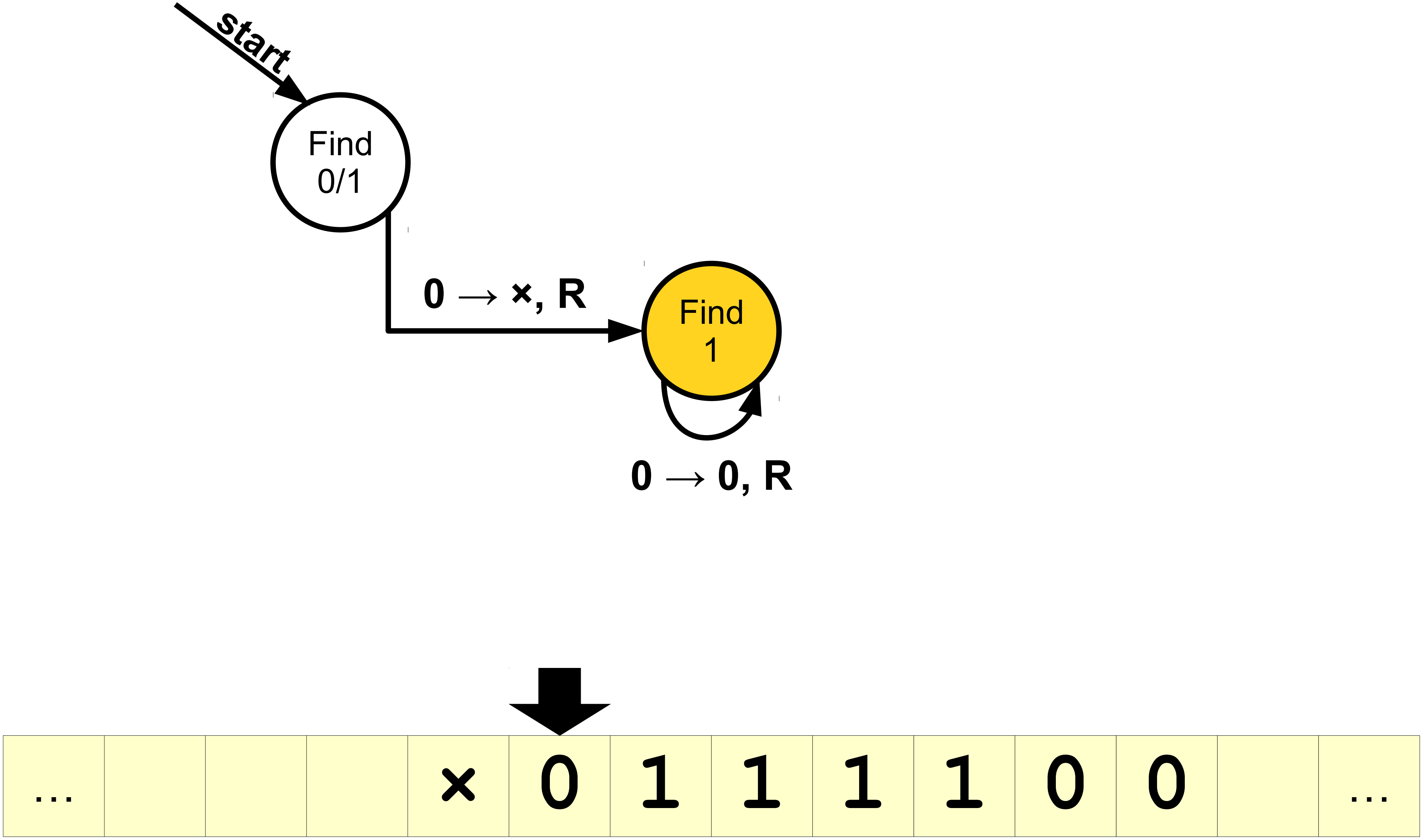
…				0	0	1	1	1	1	0	0		…

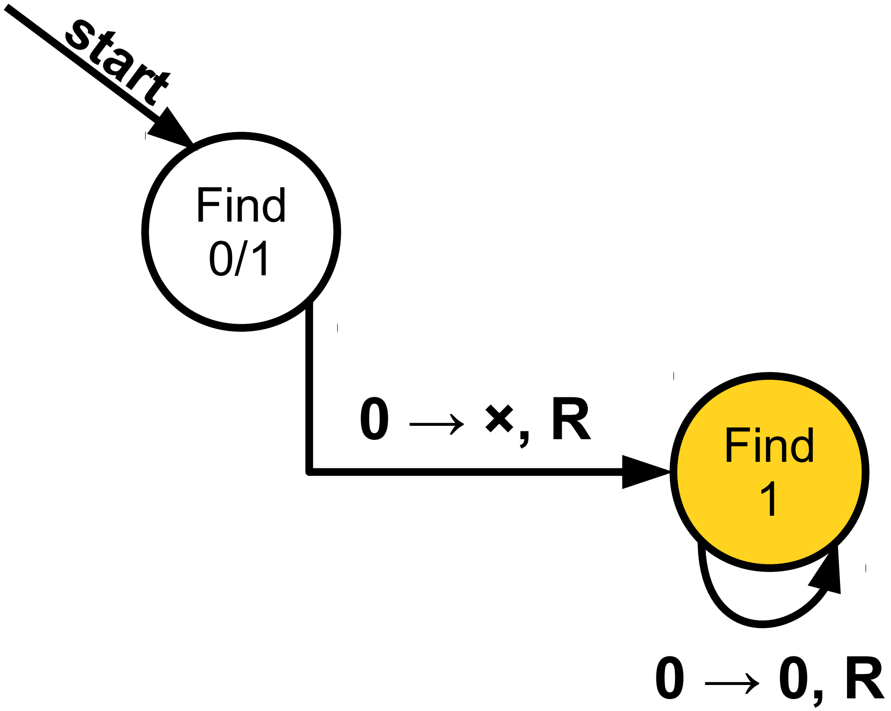

start
Find 0/1
0 → ×, R
…
×
0
1
1
1
1
0
0
…

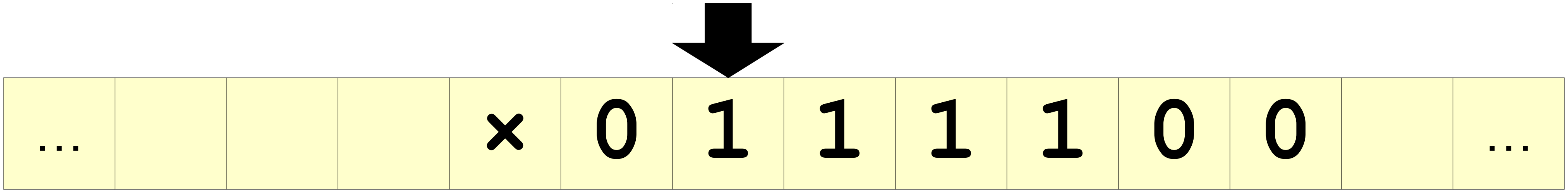




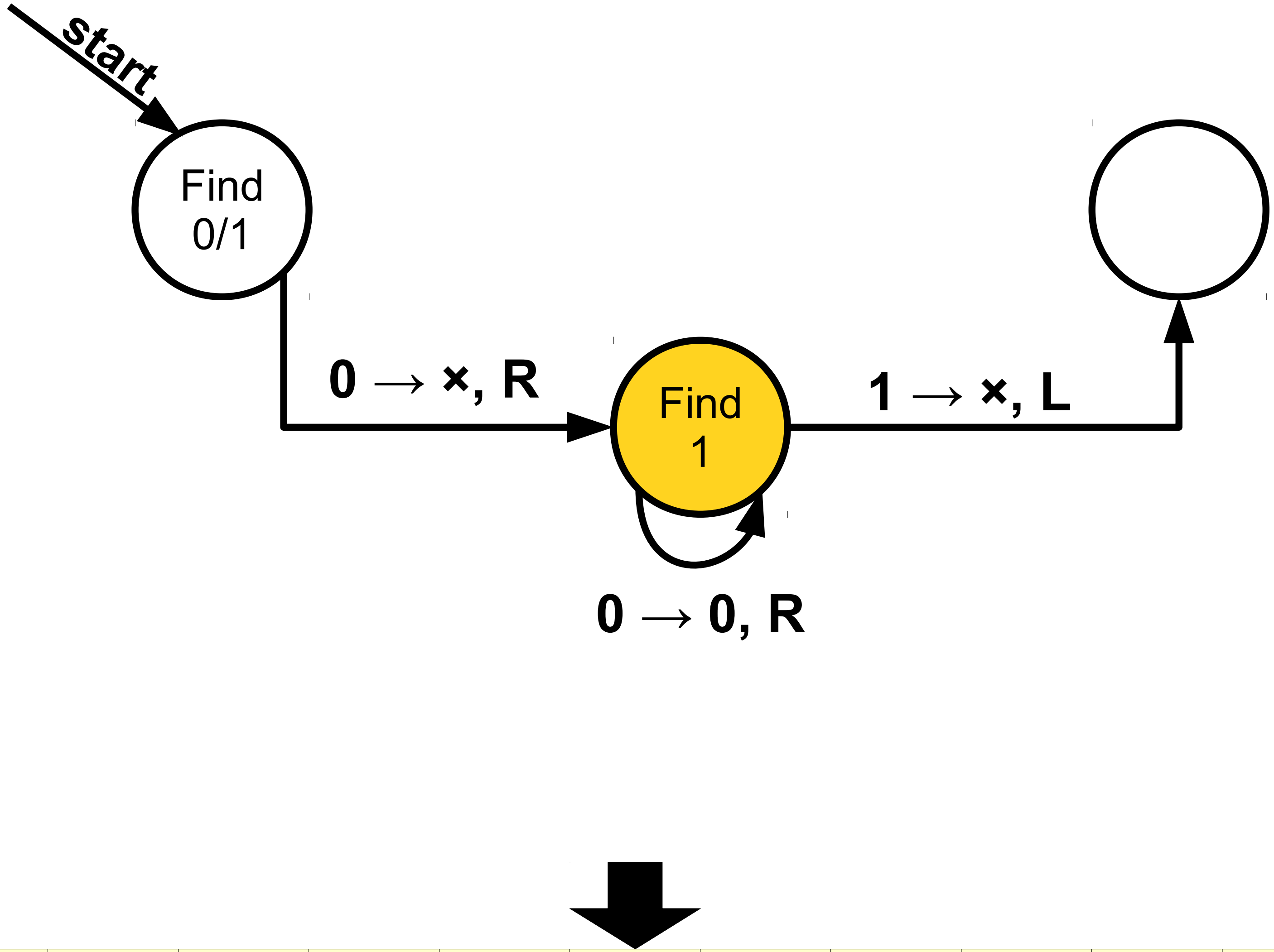
…				×	0	1	1	1	1	0	0		…


start
Find 0/1
0 → ×, R
Find 1
0 → 0, R
… × 0 1 1 1 1 0 0 …

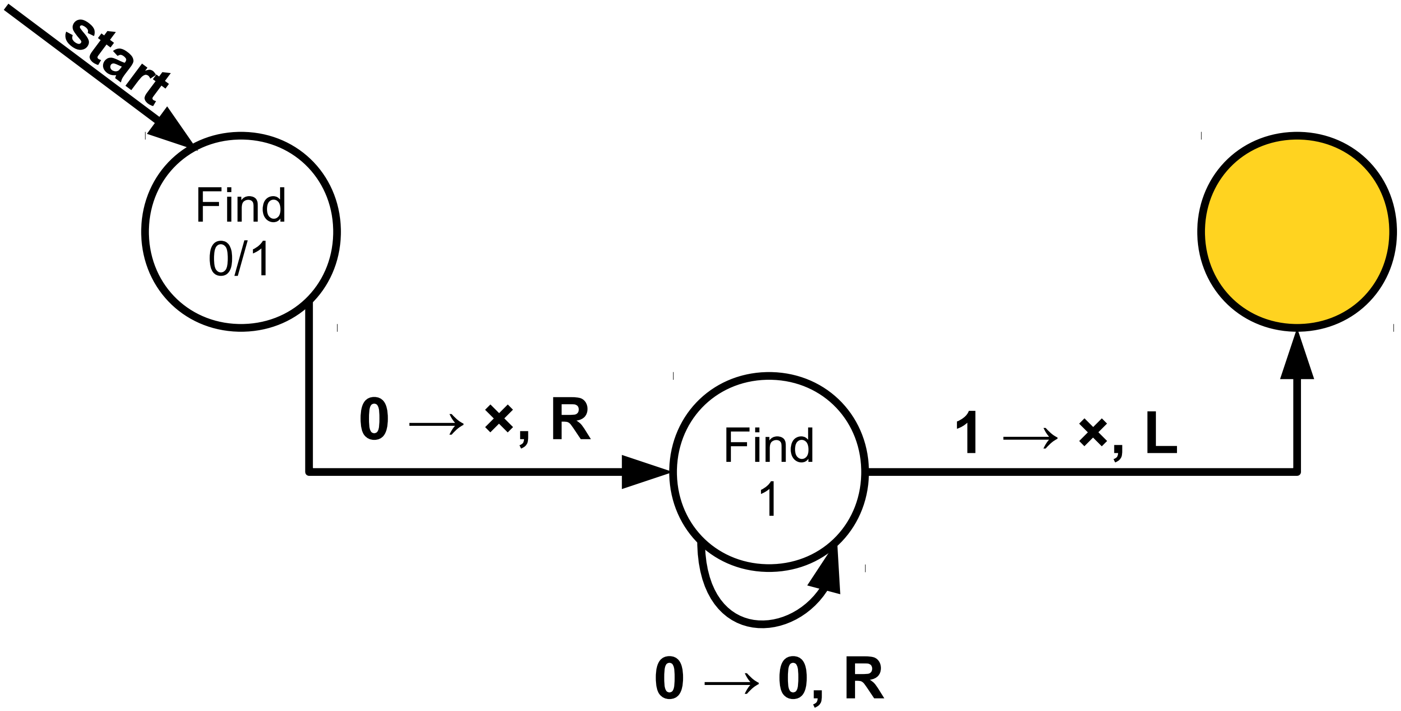


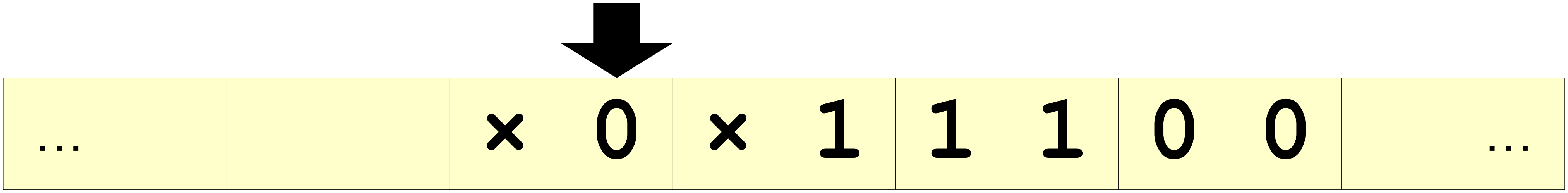


…				×	0	1	1	1	1	0	0		…

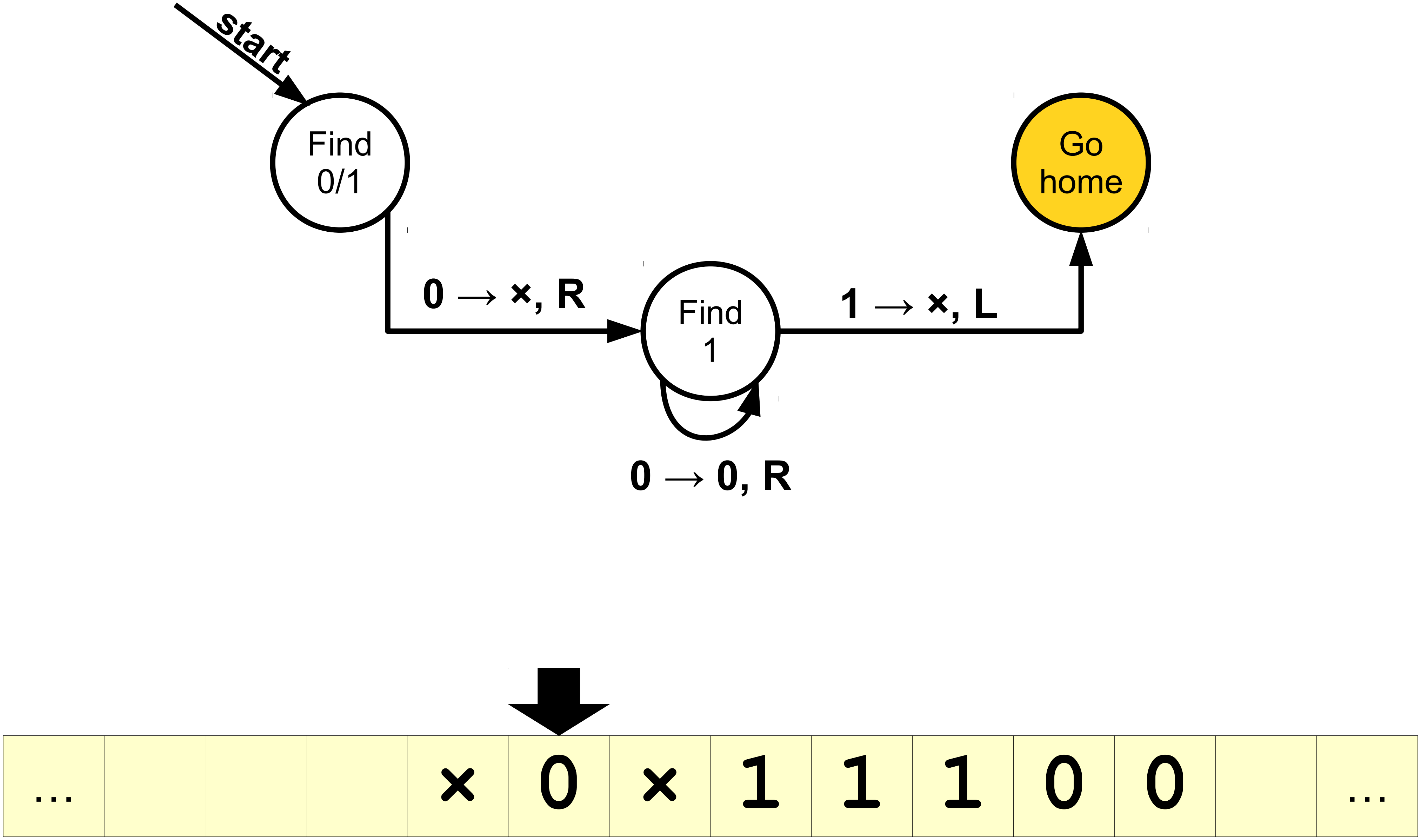


…				×	0	1	1	1	1	0	0		…

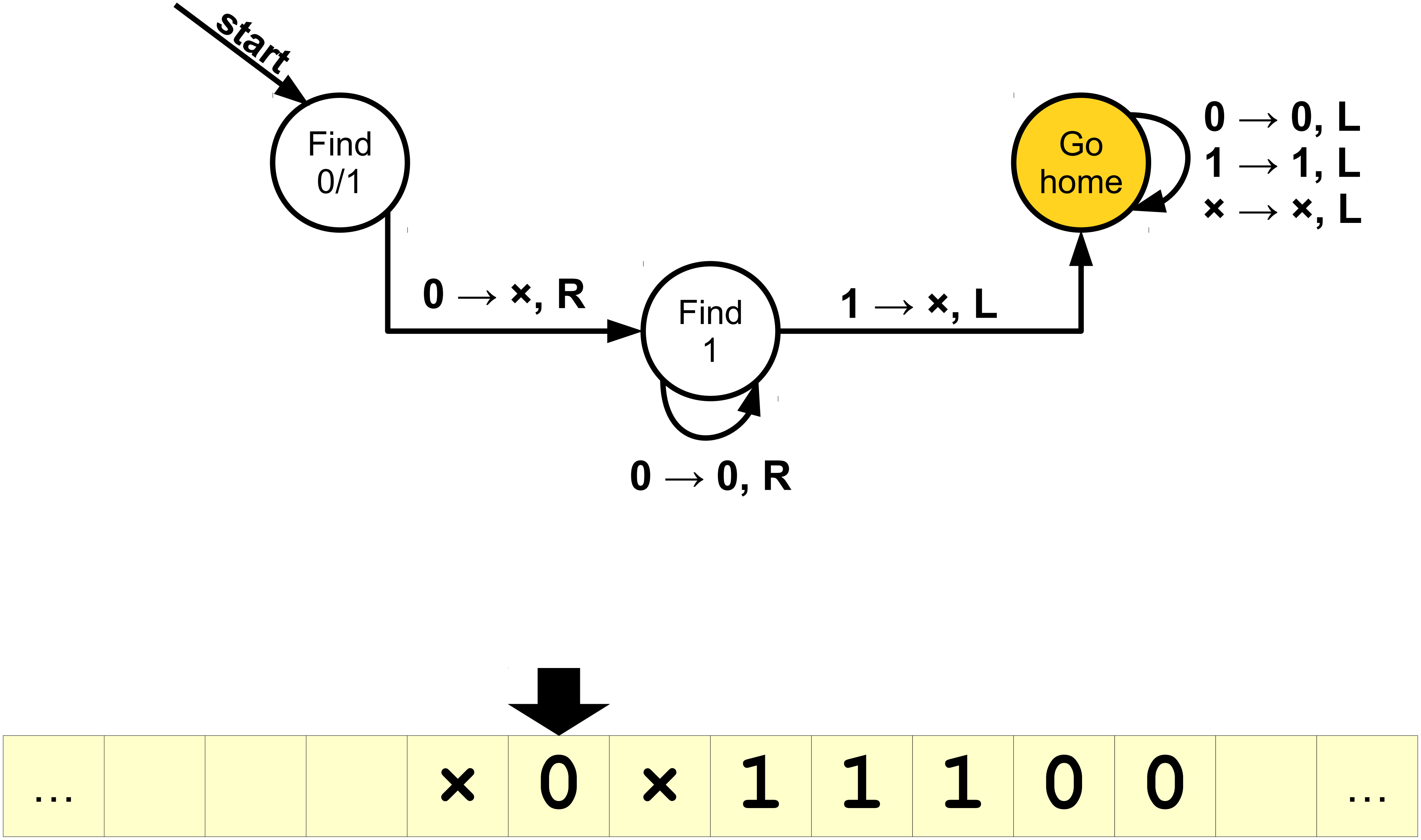


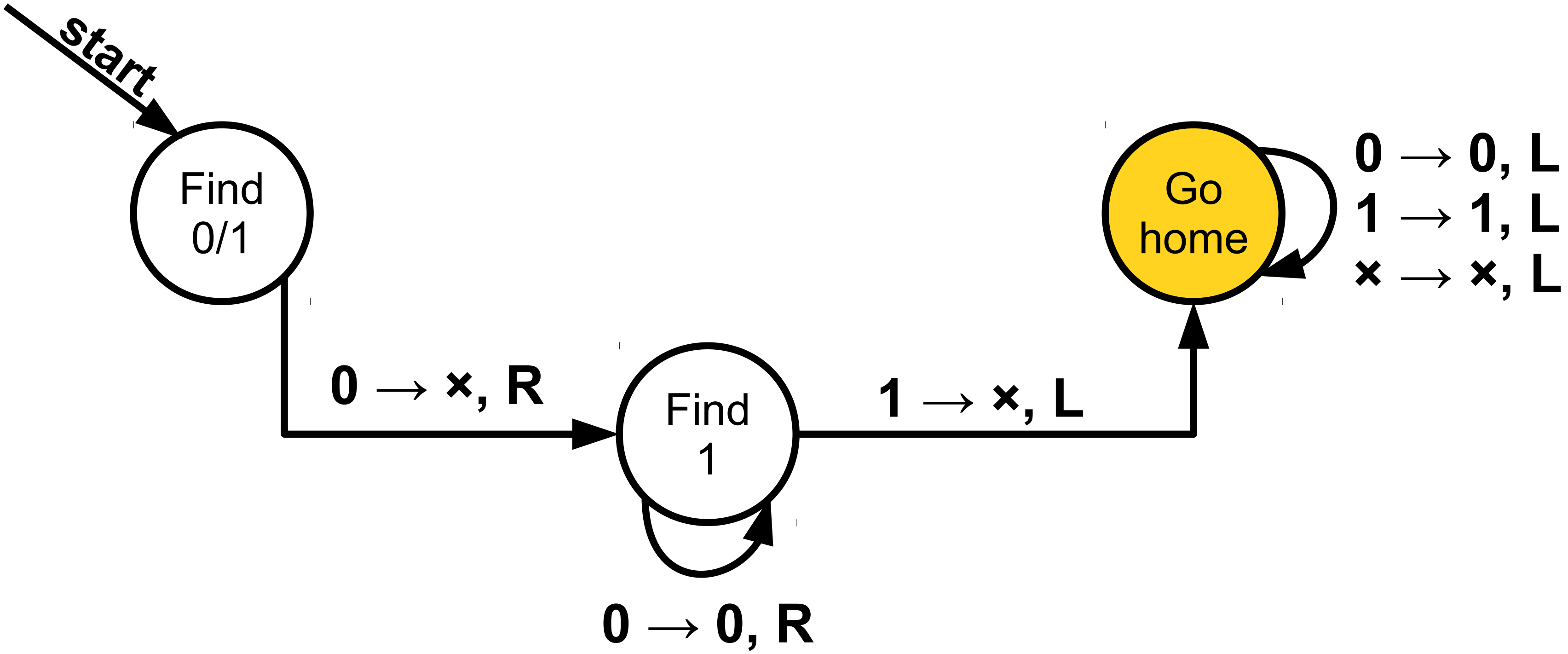


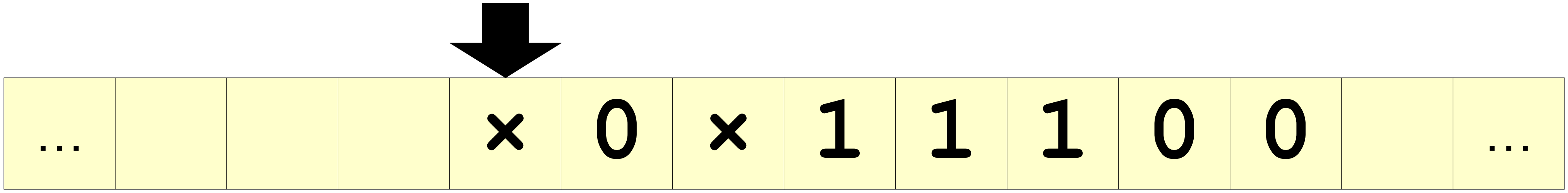
…				×	0	×	1	1	1	0	0		…

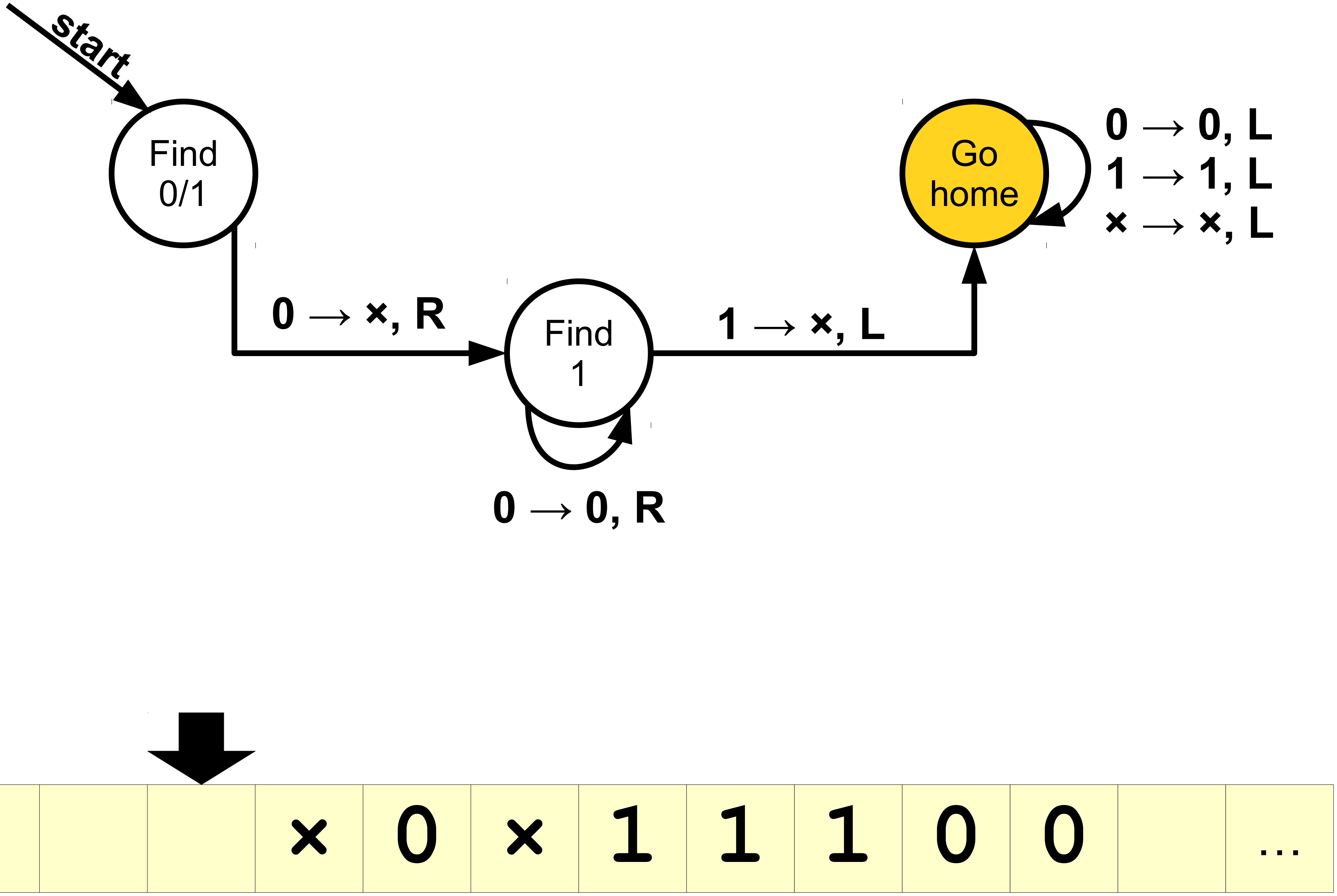


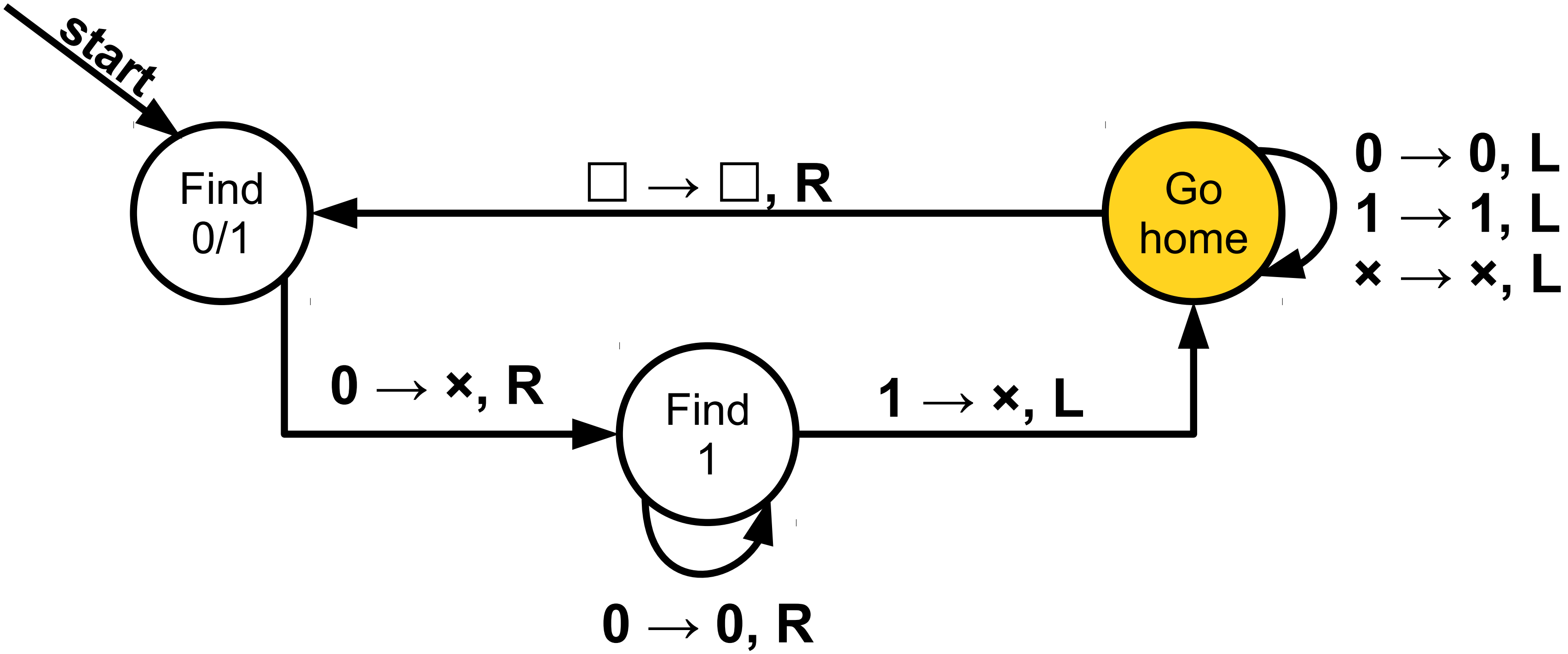
…				×	0	×	1	1	1	0	0		…

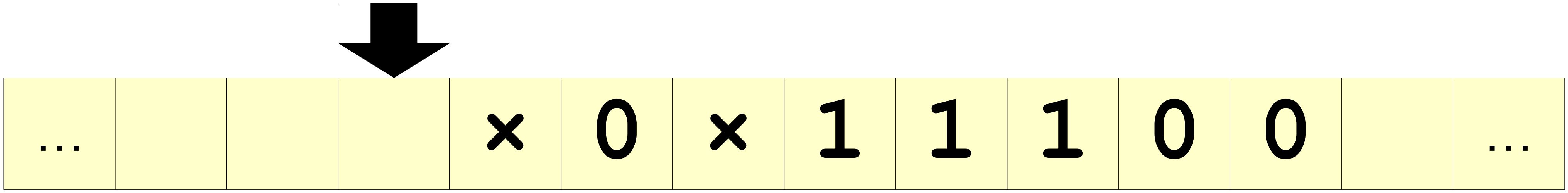

start
Find 0/1
0 → ×, R
Find 1
0 → 0, R
1 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
…
×
0
×
1
1
1
0
0
…


start
Find 0/1
0 → ×, R
Find 1
0 → 0, R
1 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L

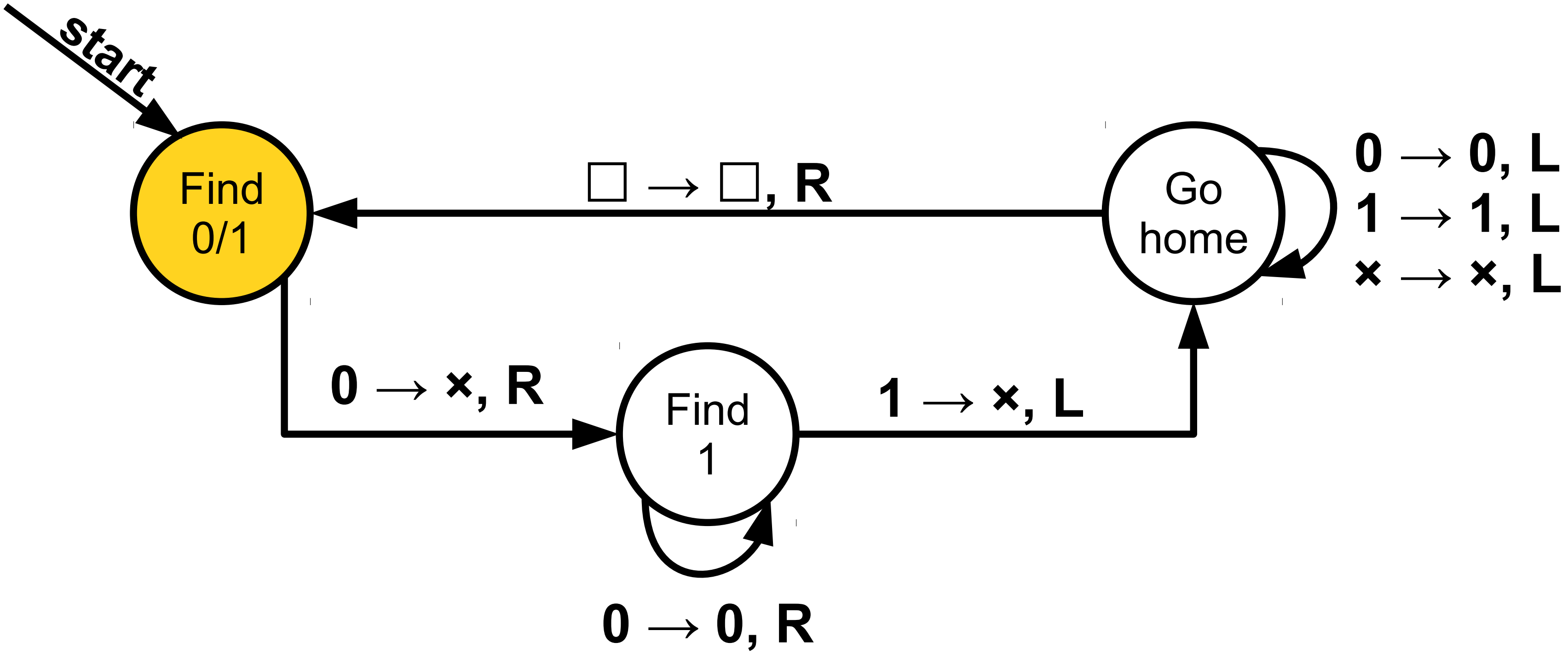

…
×
0
×
1
1
1
0
0
…

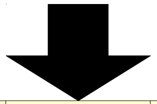

start
Find 0/1
0 → ×, R
Find 1
0 → 0, R
1 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
…
×
0
×
1
1
1
0
0
…



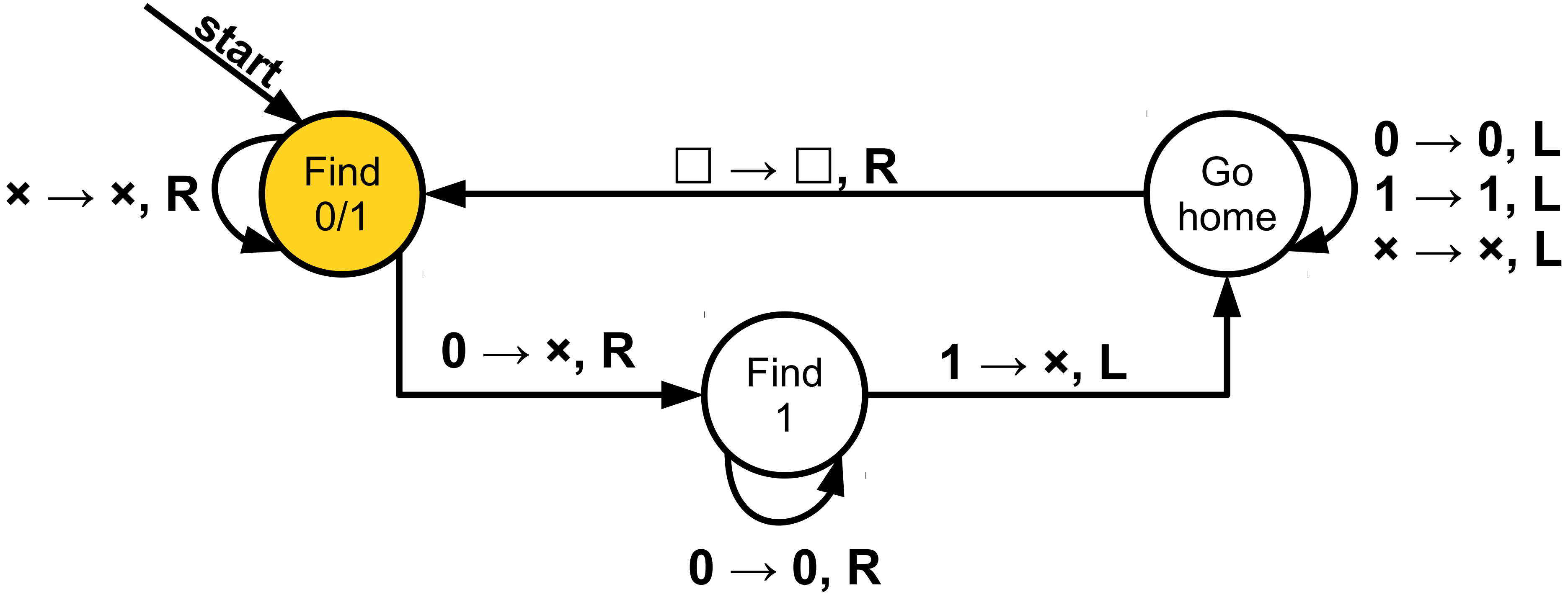


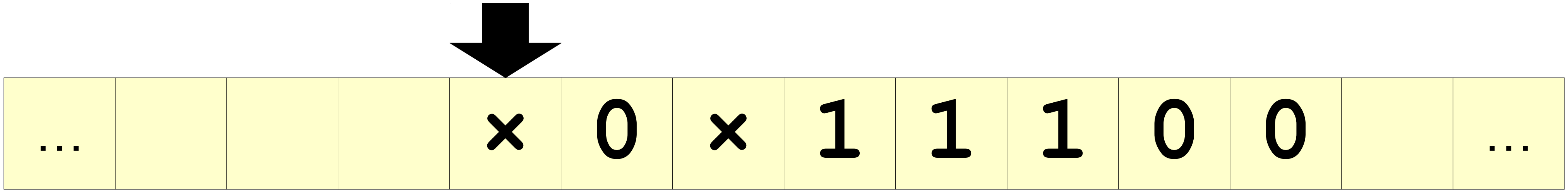
…				×	0	×	1	1	1	0	0		…



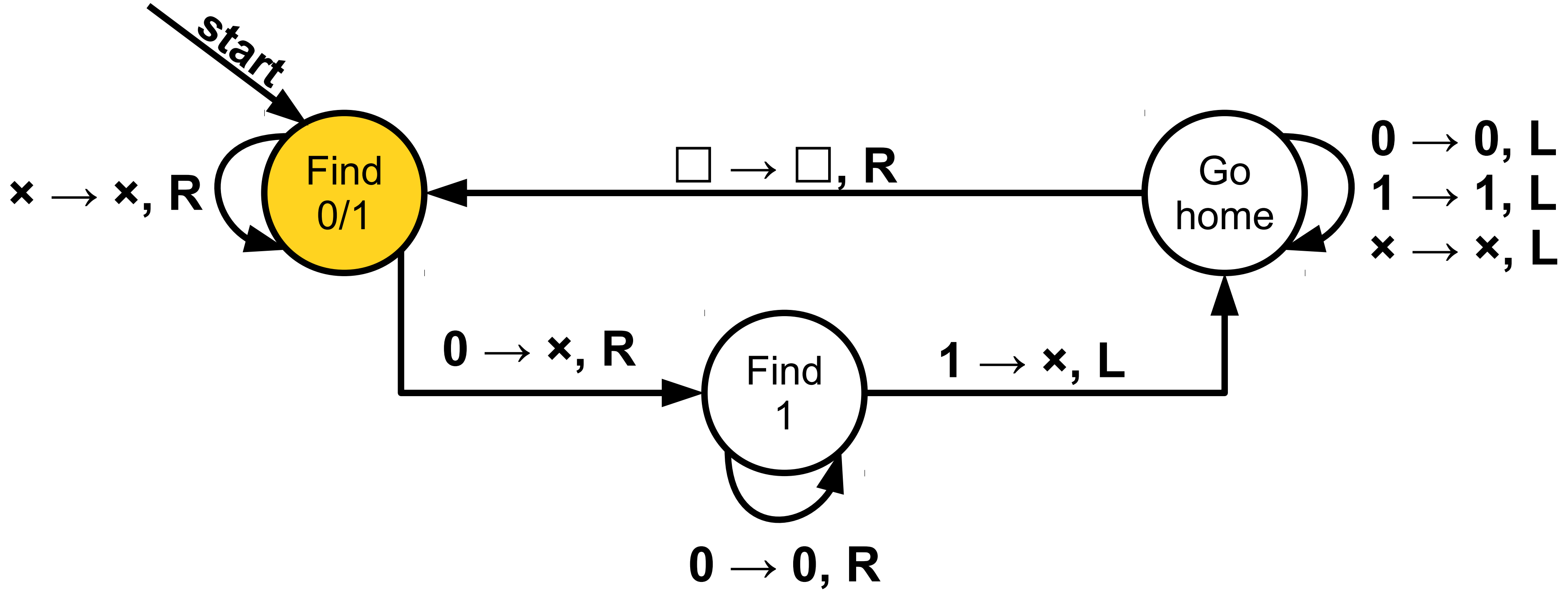


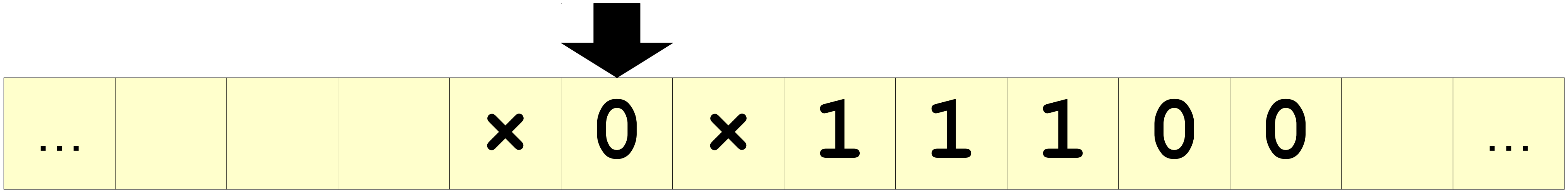
…				×	0	×	1	1	1	0	0		…



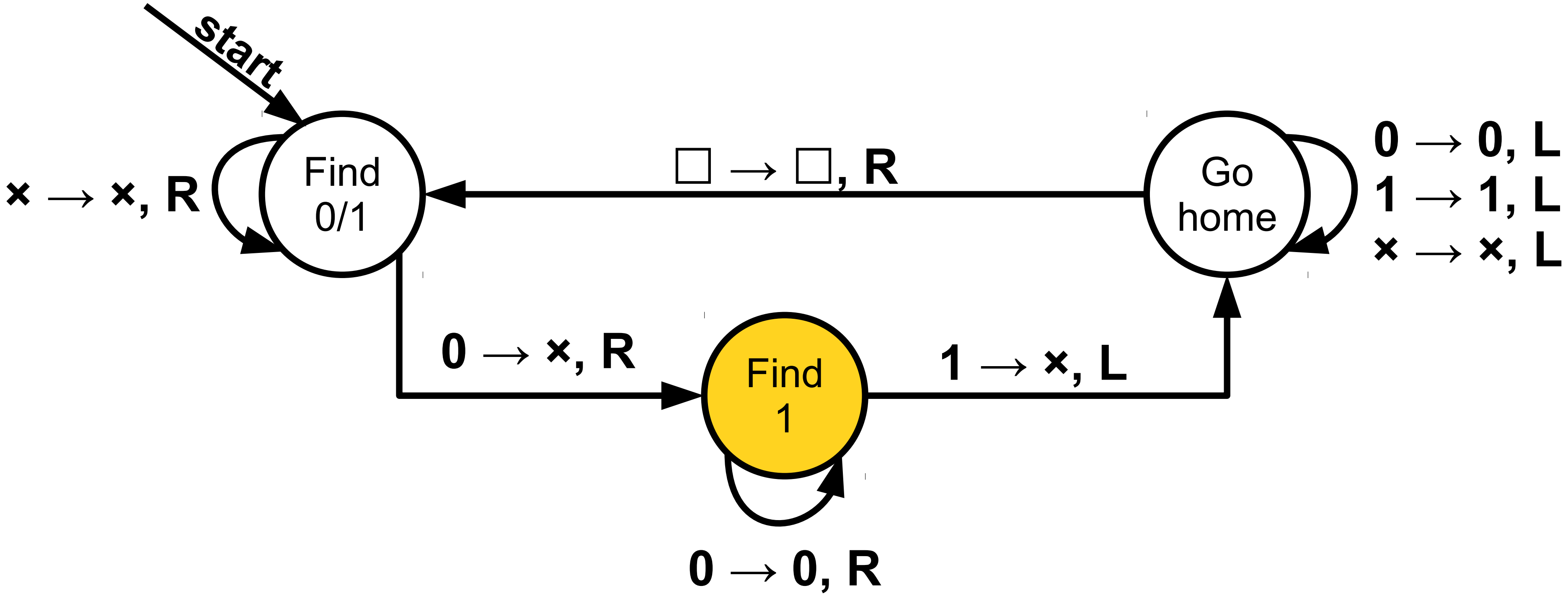


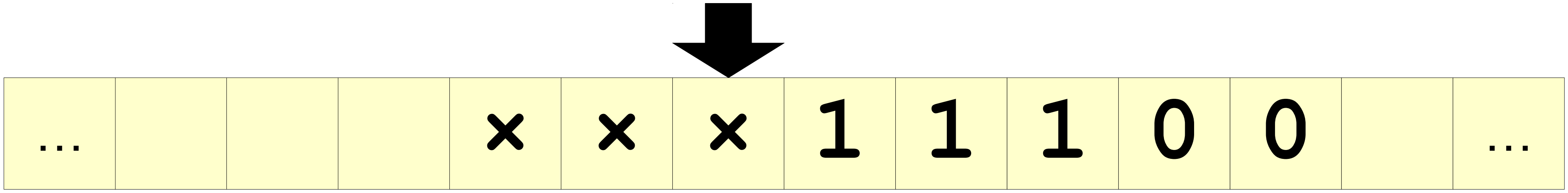
…				×	0	×	1	1	1	0	0		…

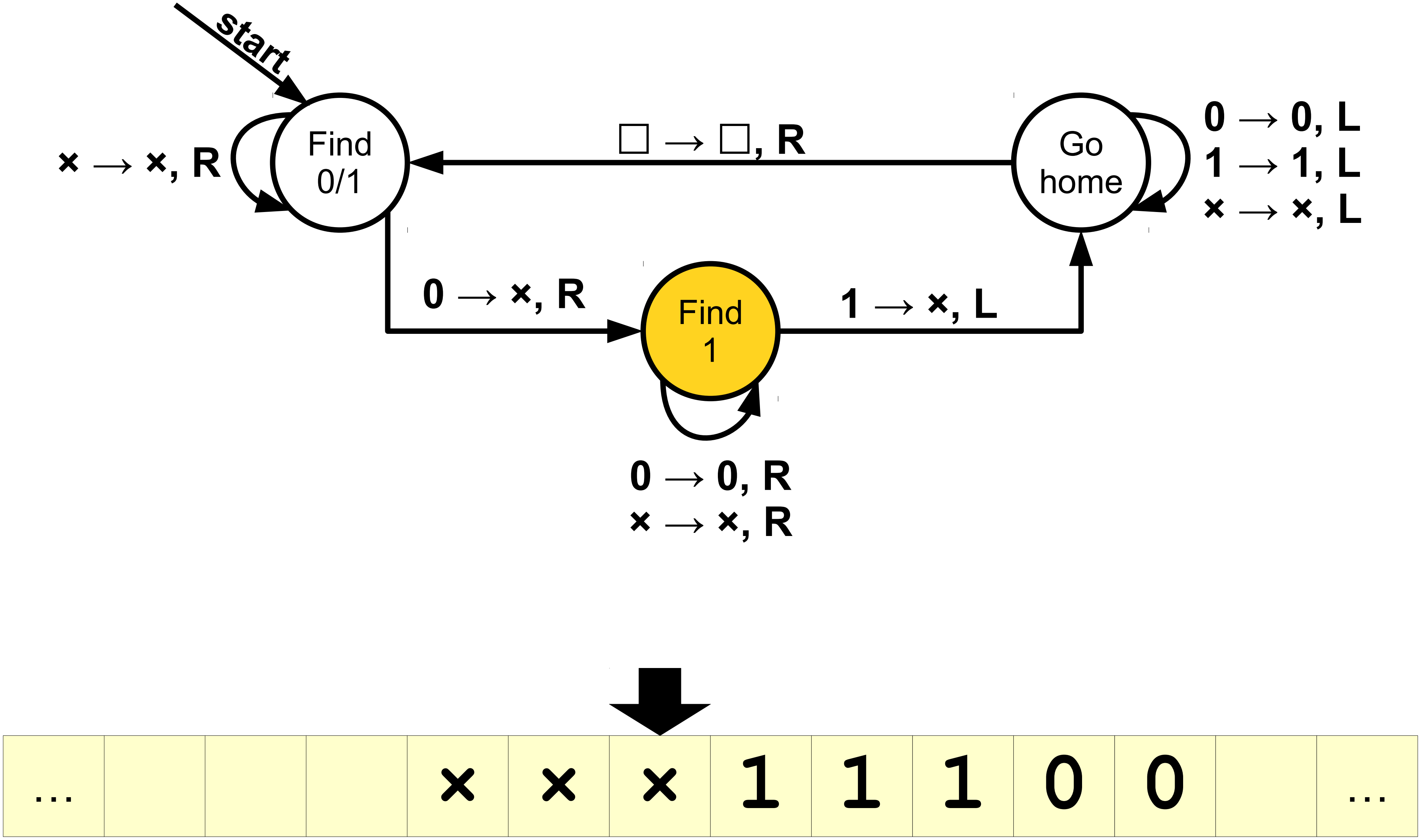


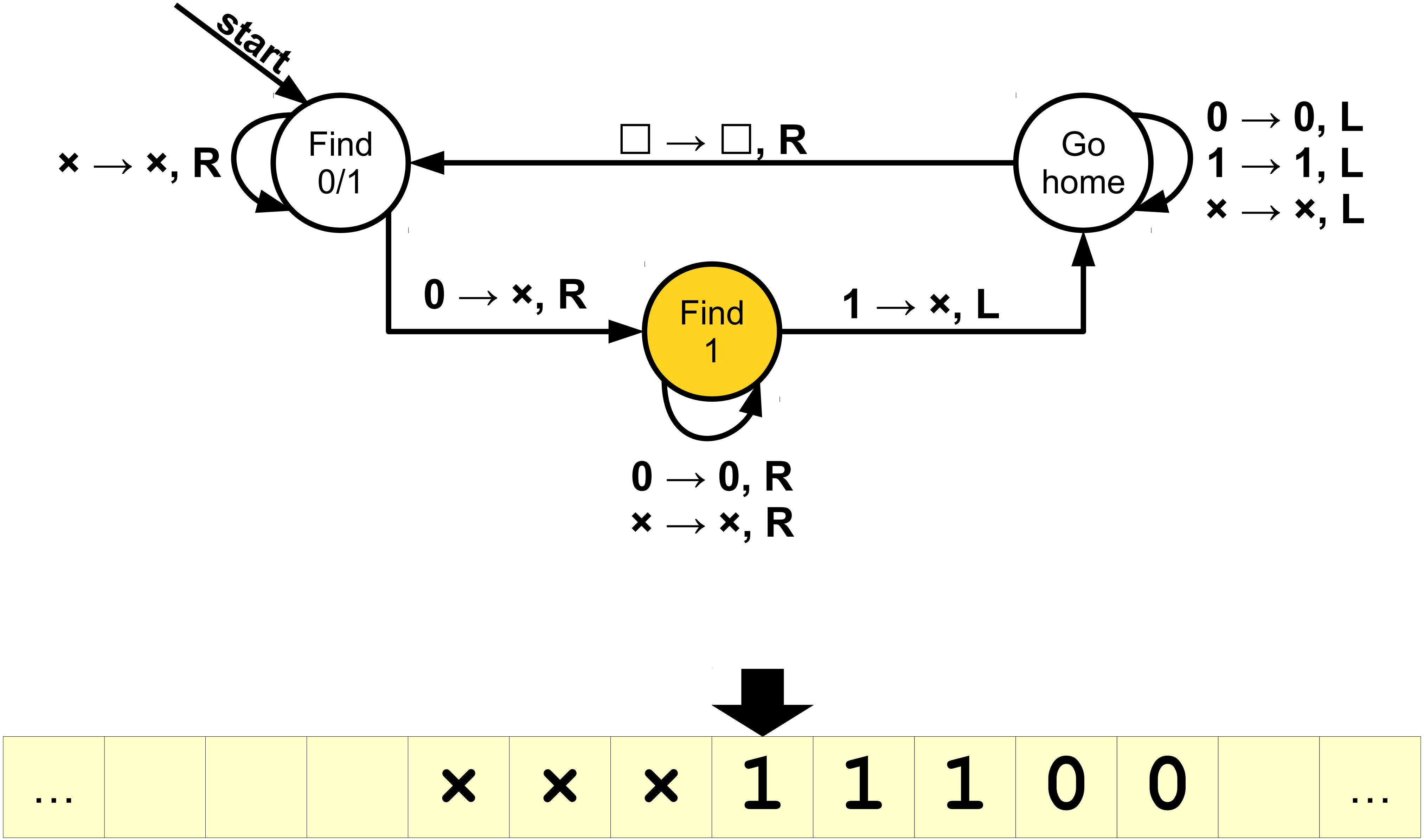


…				×	0	×	1	1	1	0	0		…


start
× → ×, R
Find 0/1
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R


…
×
×
×
1
1
1
0
0
…


start
Find 0/1
× → ×, R
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R
…
×
×
×
1
1
1
0
0
…



start

Find 0/1

× → ×, R

□ → □, R

Go home

0 → 0, L
1 → 1, L
× → ×, L

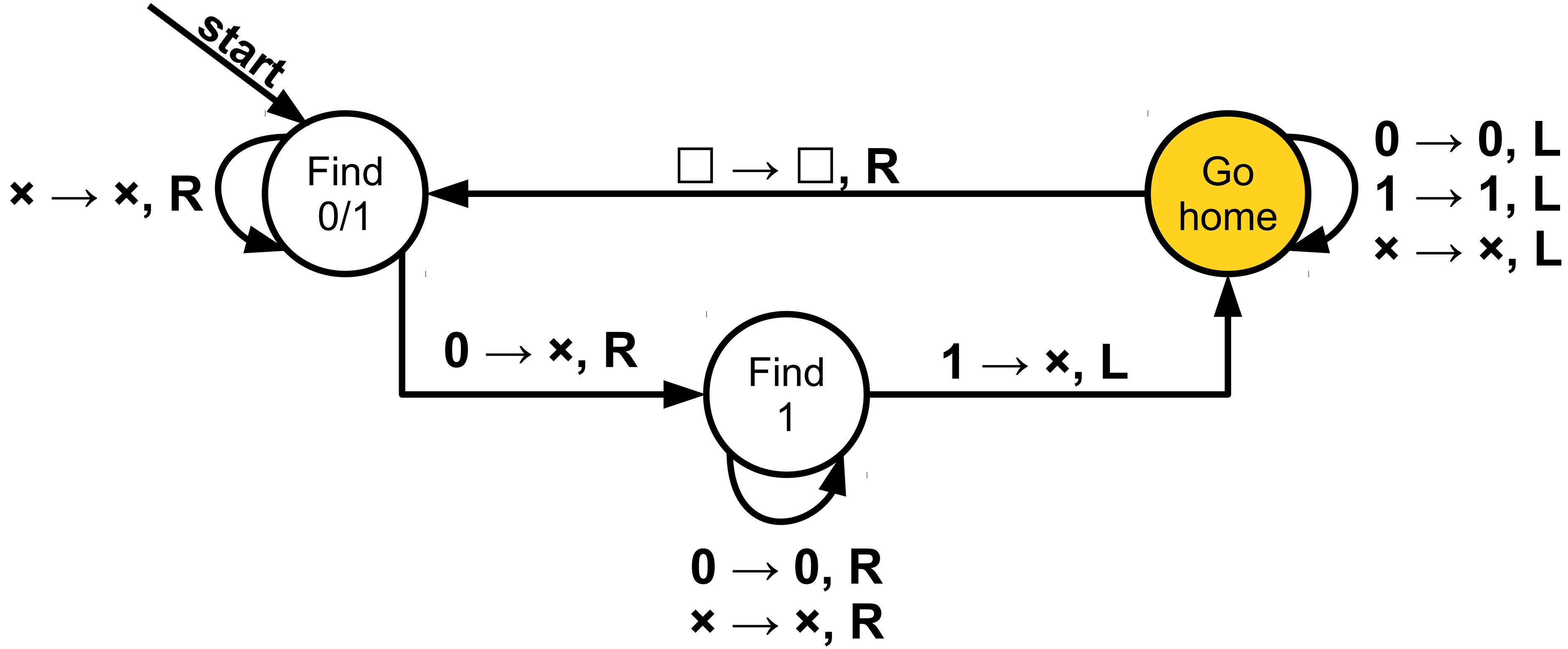
0 → ×, R

Find 1

1 → ×, L

0 → 0, R
× → ×, R

… × × × 1 1 1 0 0 …



start

Find 0/1

× → ×, R

□ → □, R

Go home

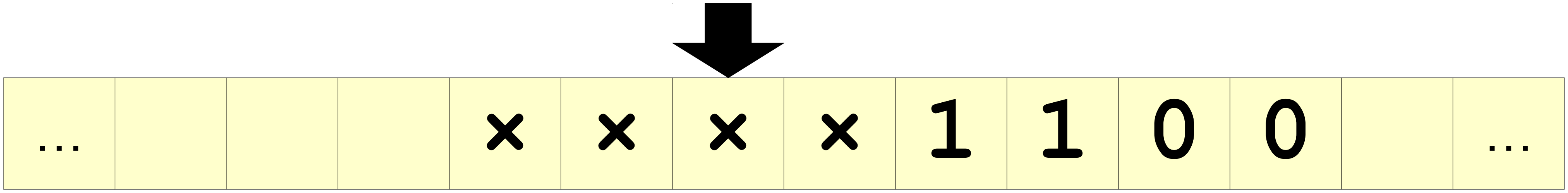
0 → 0, L
1 → 1, L
× → ×, L

0 → ×, R

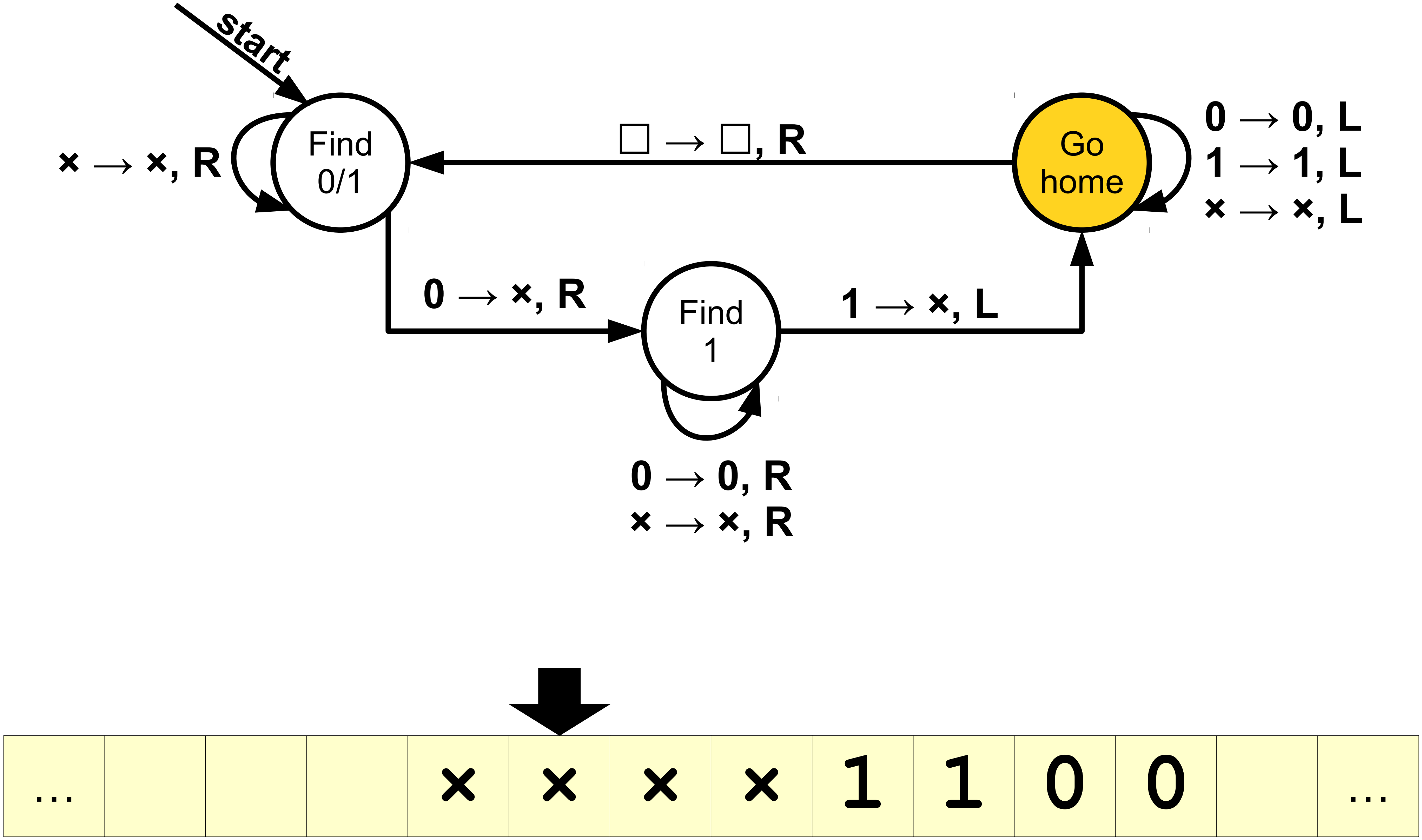
Find 1

1 → ×, L

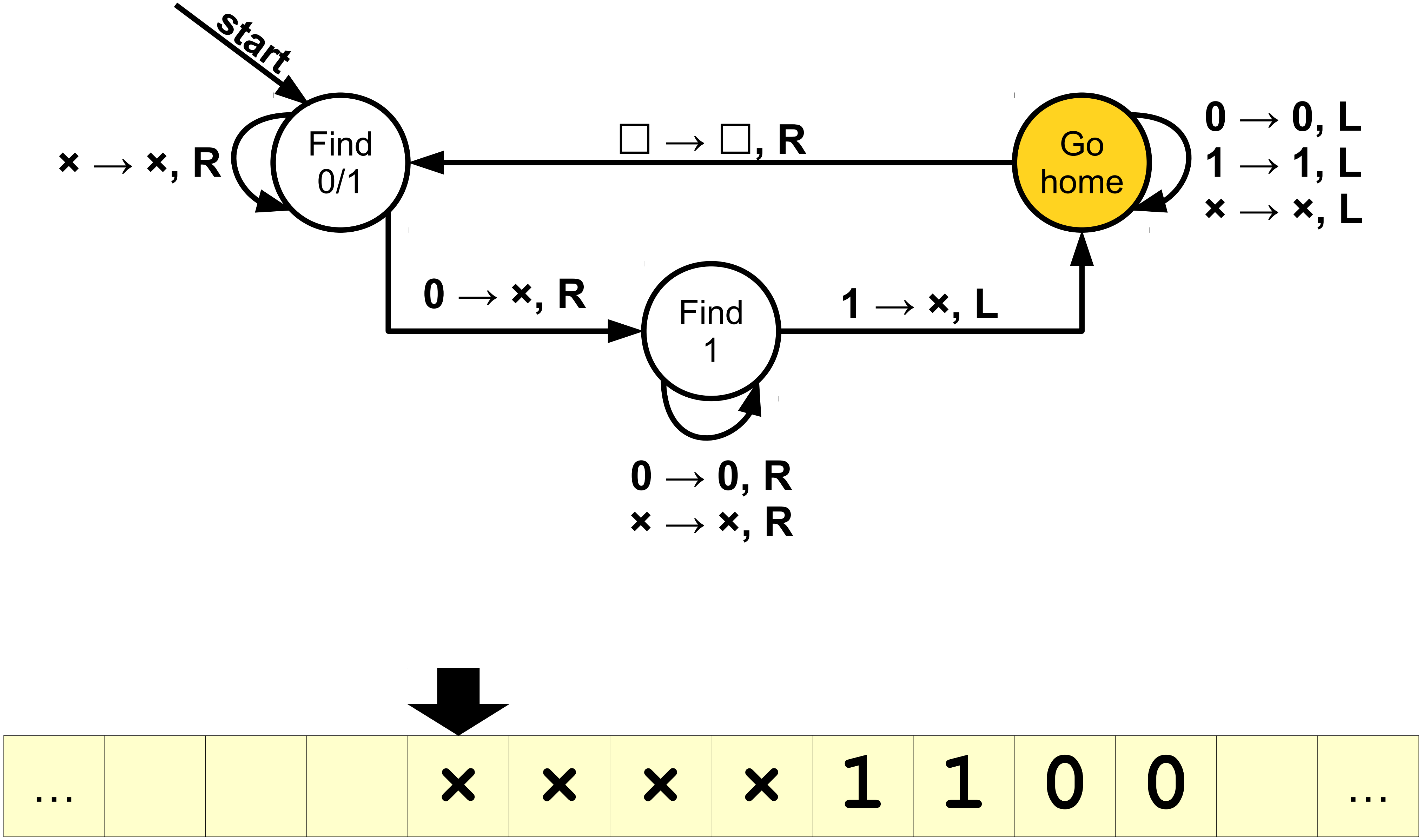
0 → 0, R
× → ×, R



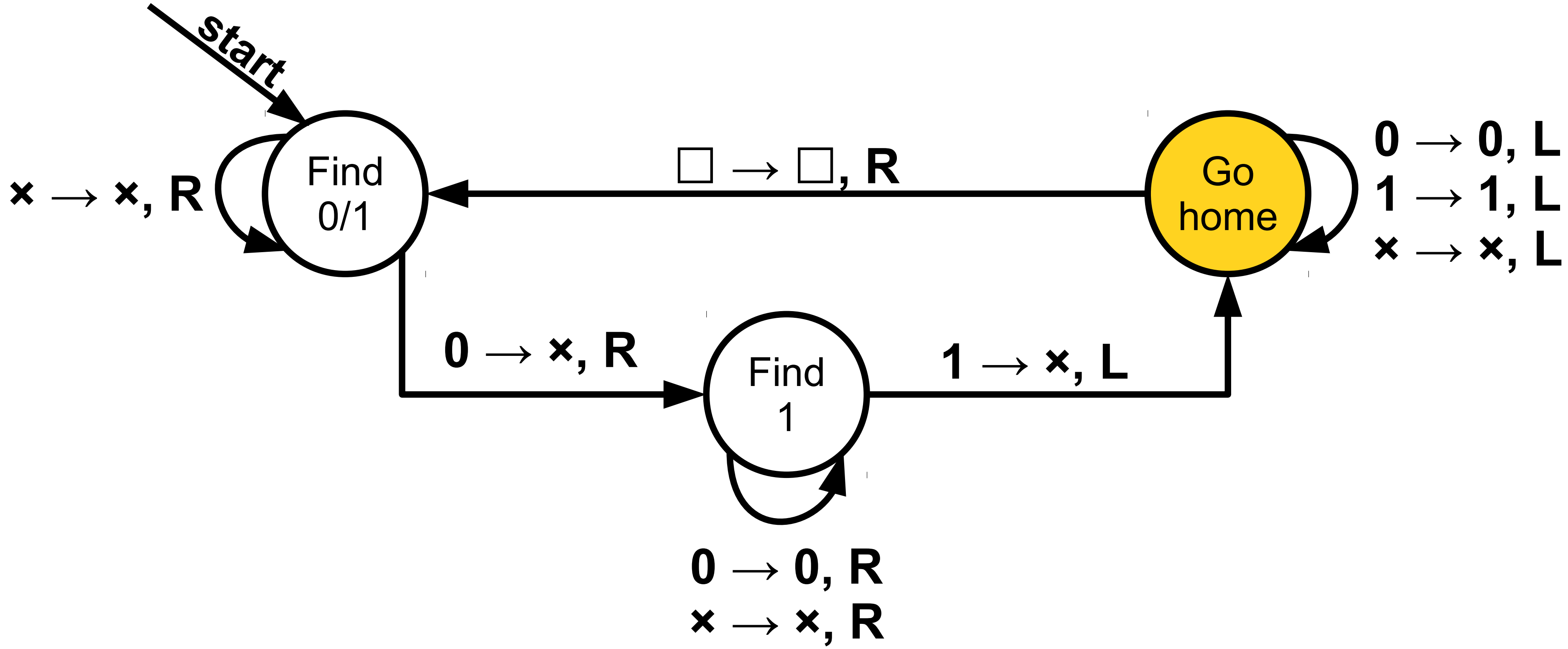
…				×	×	×	×	1	1	0	0		…

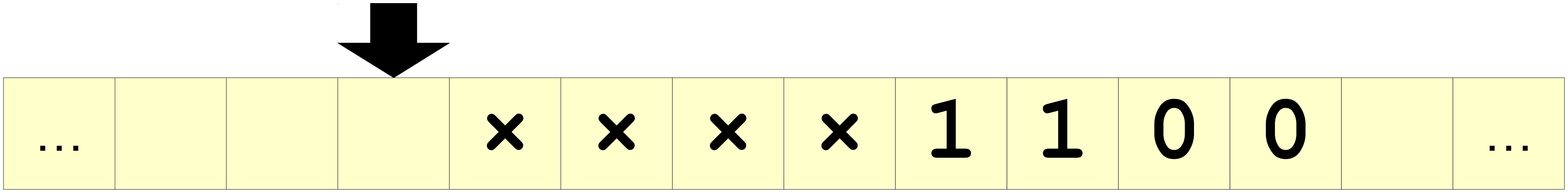


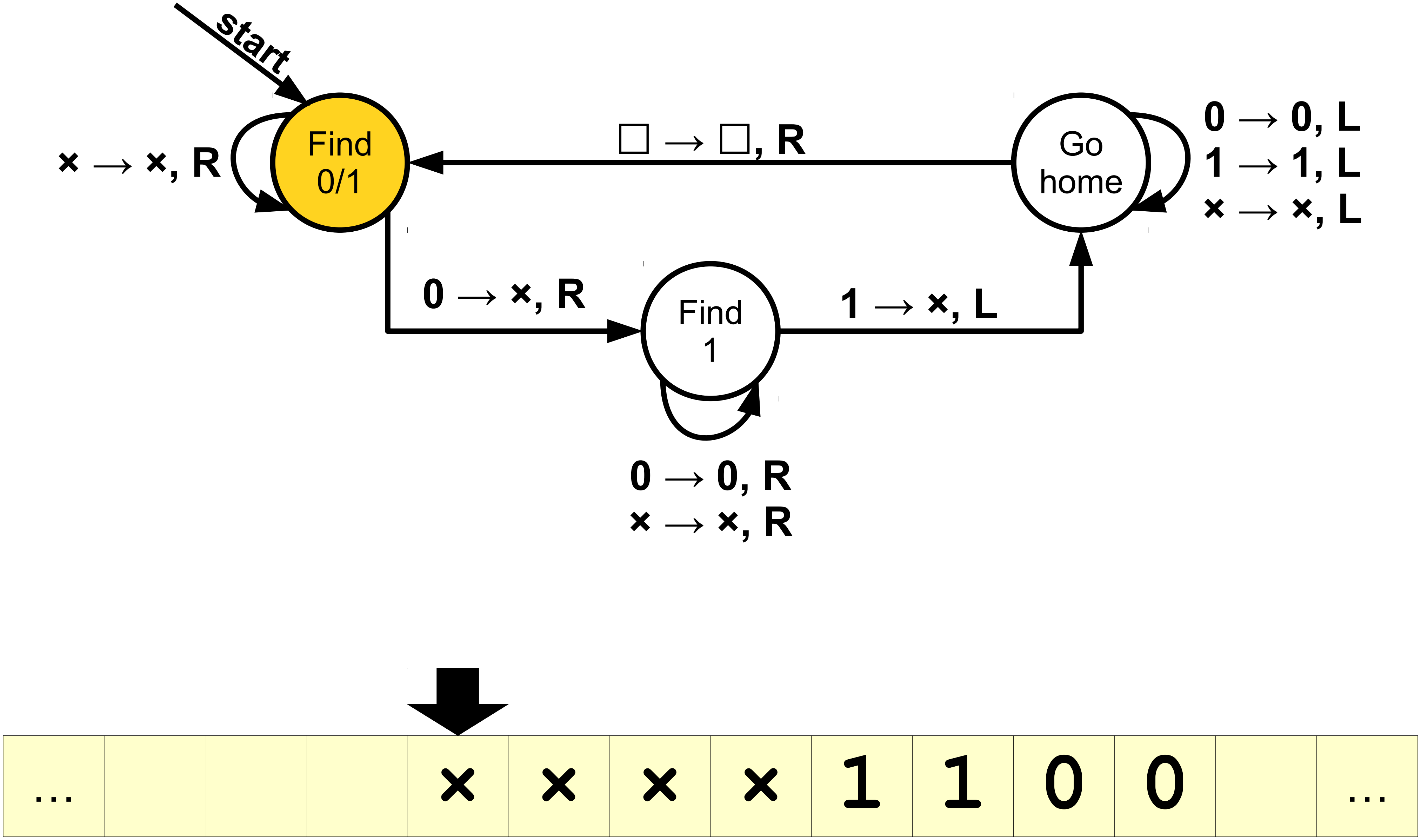
…				×	×	×	×	1	1	0	0		…



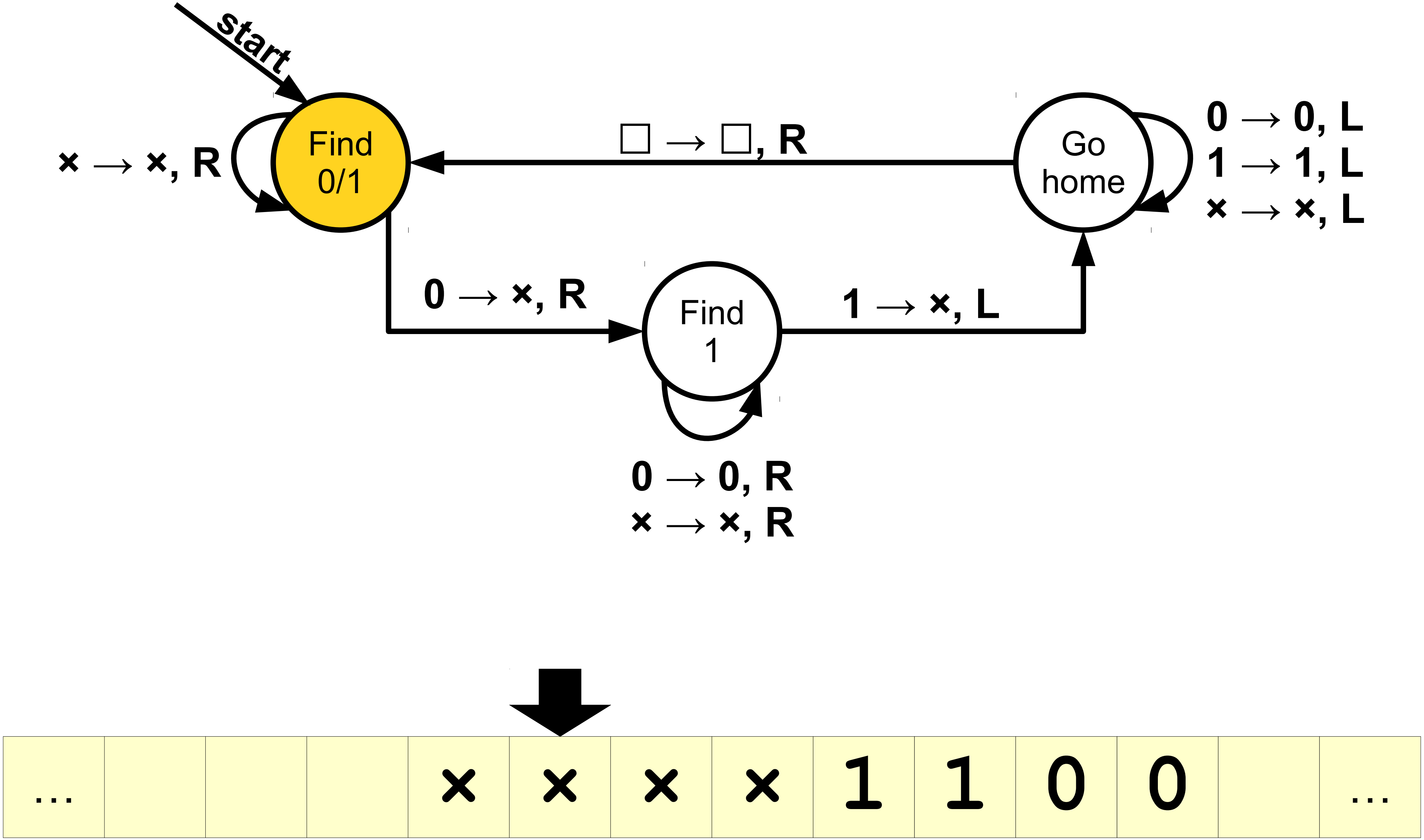
…				×	×	×	×	1	1	0	0		…

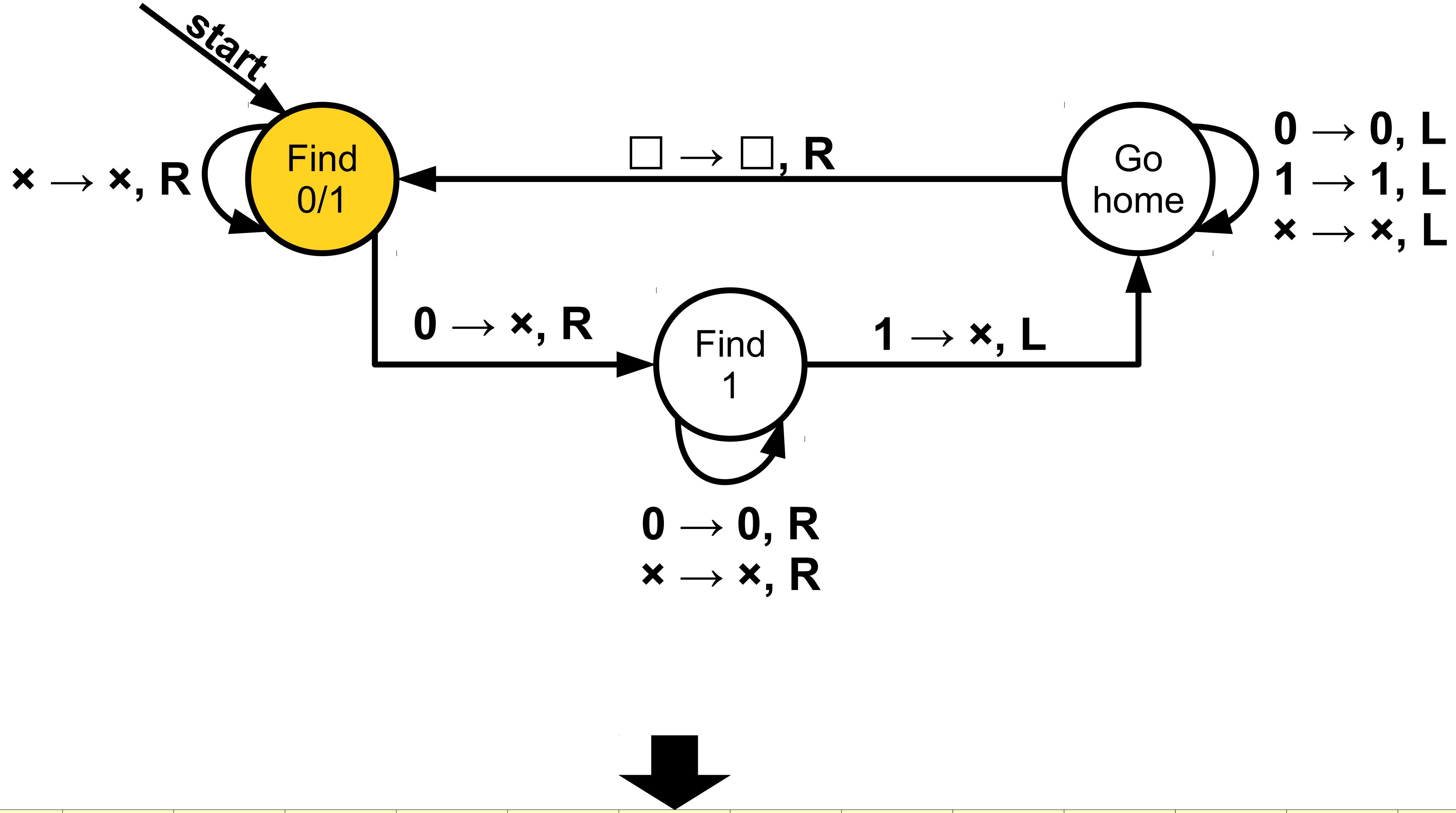

start
× → ×, R
Find 0/1
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R


…
×
×
×
×
1
1
0
0
…

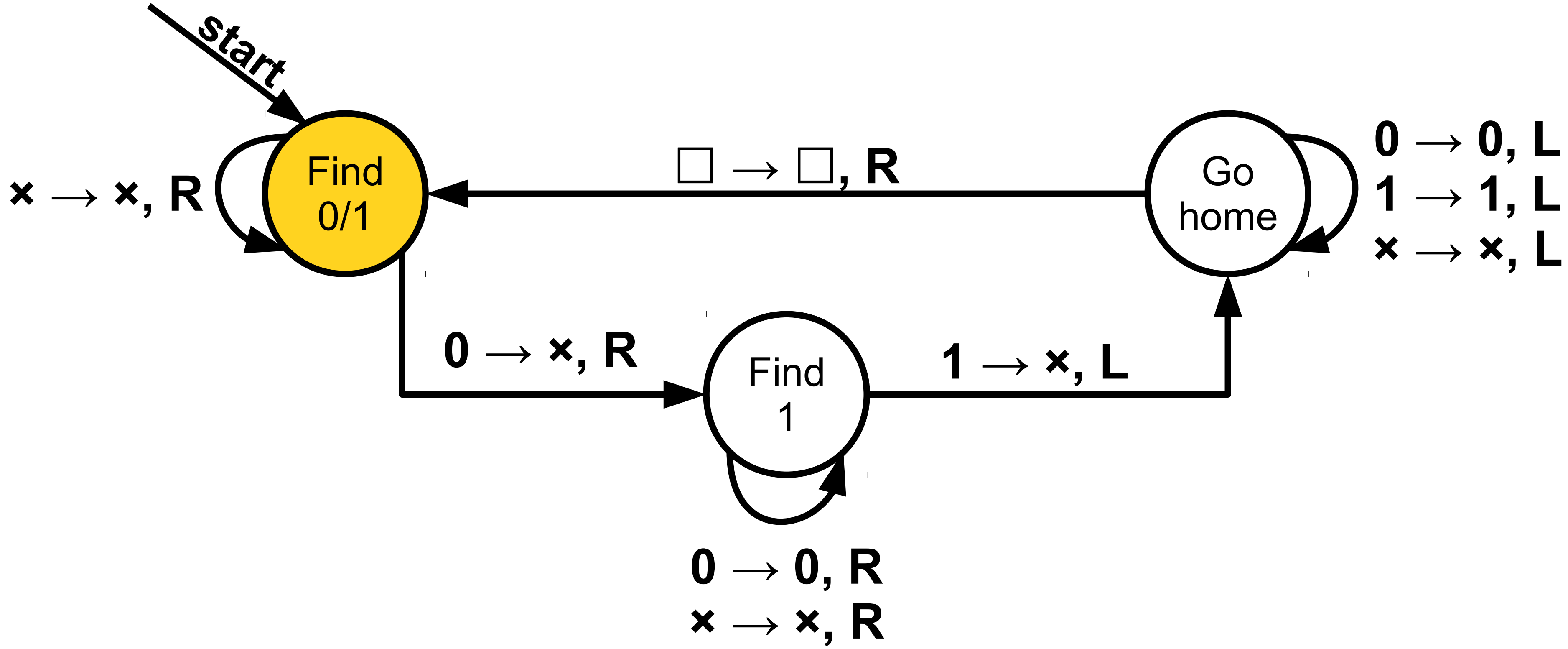


…				×	×	×	×	1	1	0	0		…

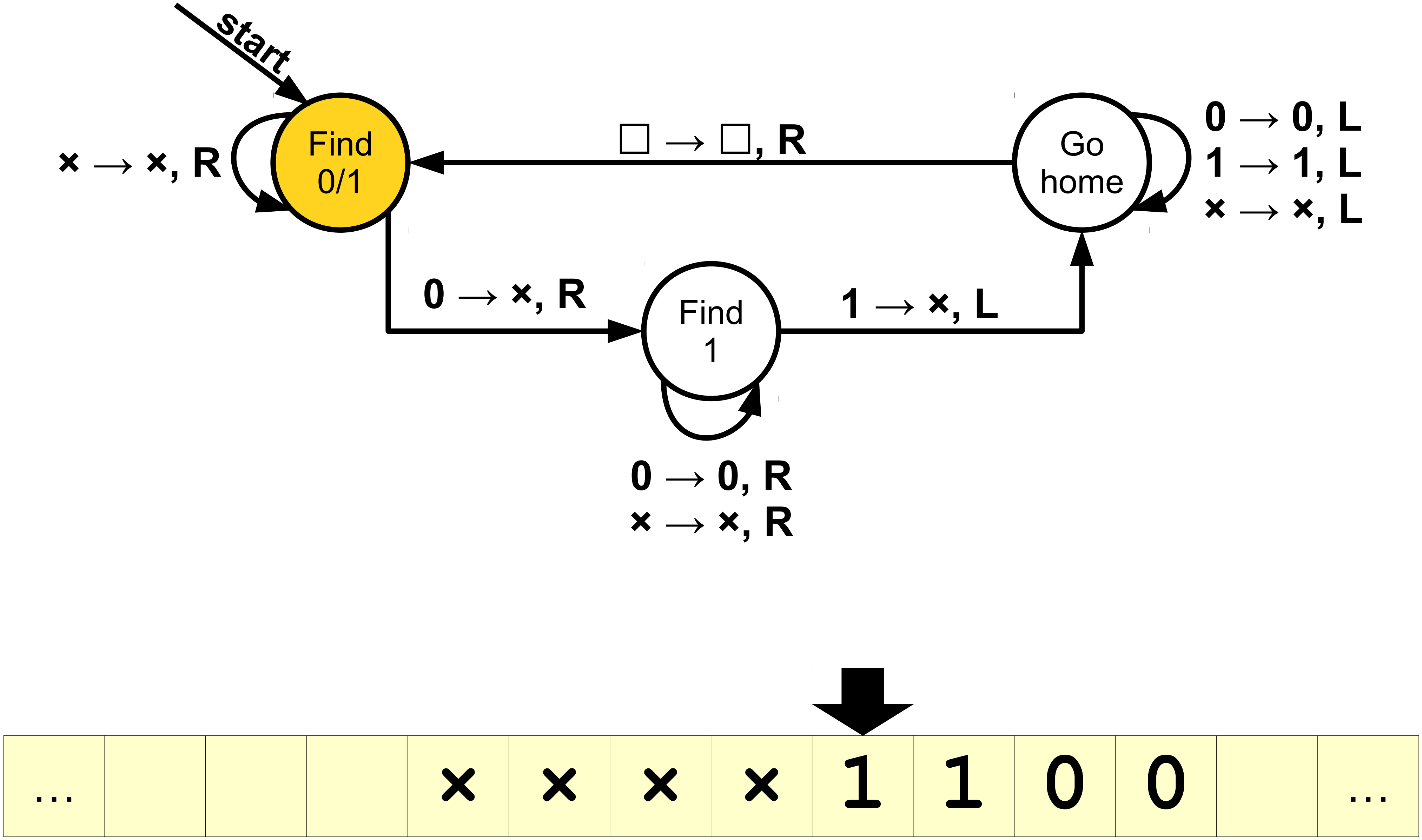

start
× → ×, R
Find 0/1
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R
…
×
×
×
×
1
1
0
0
…



…				×	×	×	×	1	1	0	0		…



…				×	×	×	×	1	1	0	0		…



start

Find 0/1

× → ×, R

□ → □, R

Go home

0 → 0, L
1 → 1, L
× → ×, L

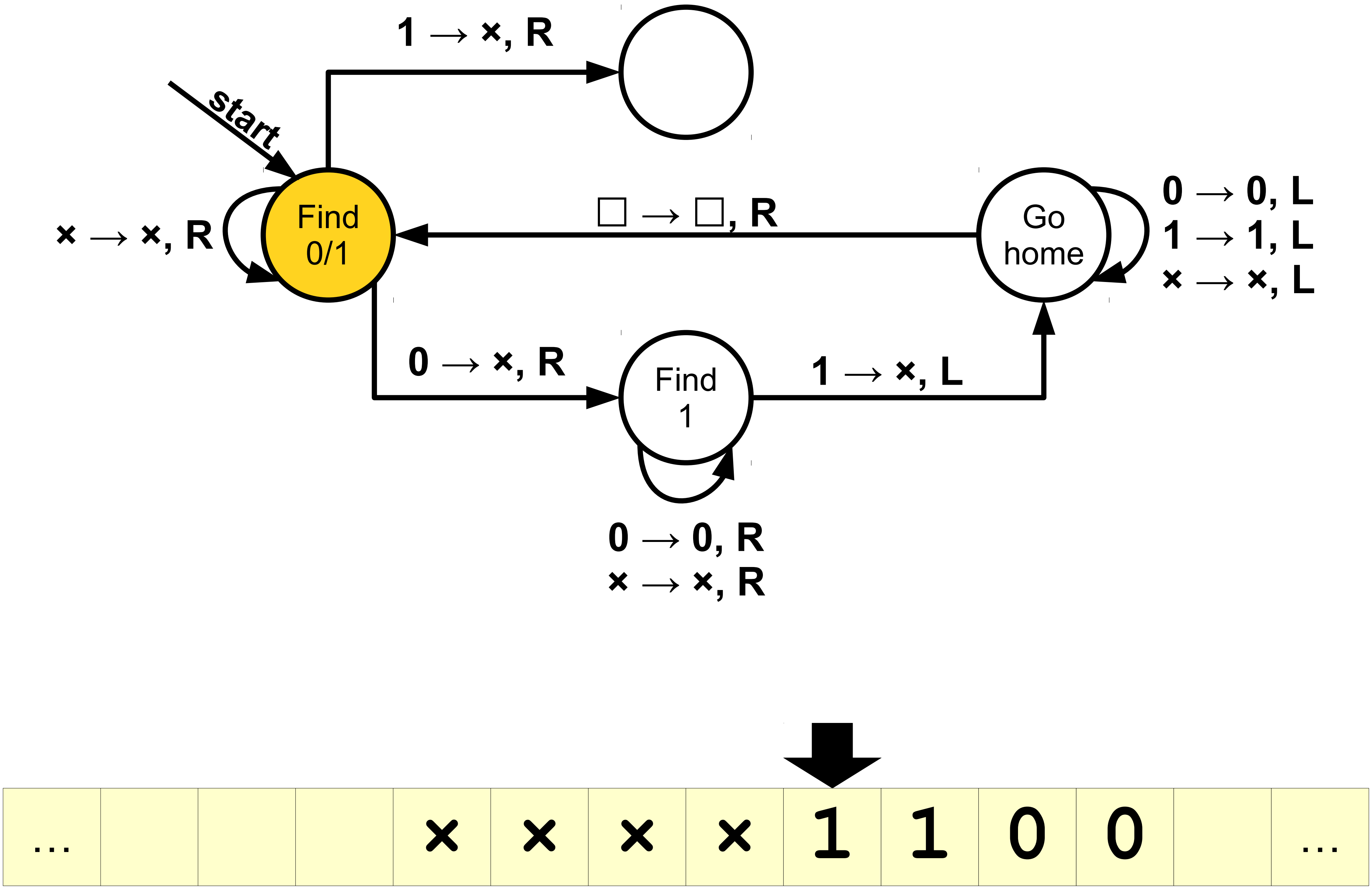
0 → ×, R

Find 1

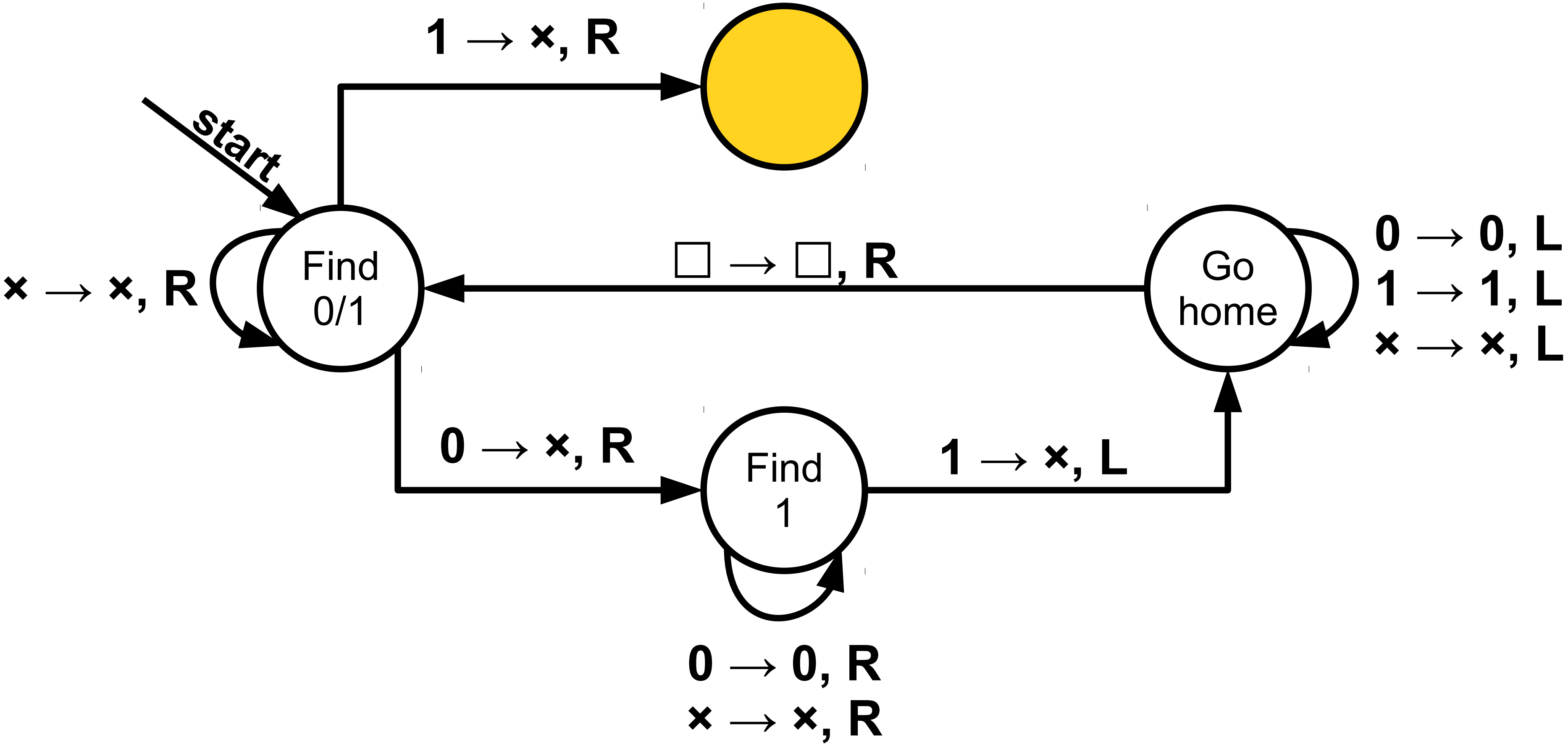
1 → ×, L

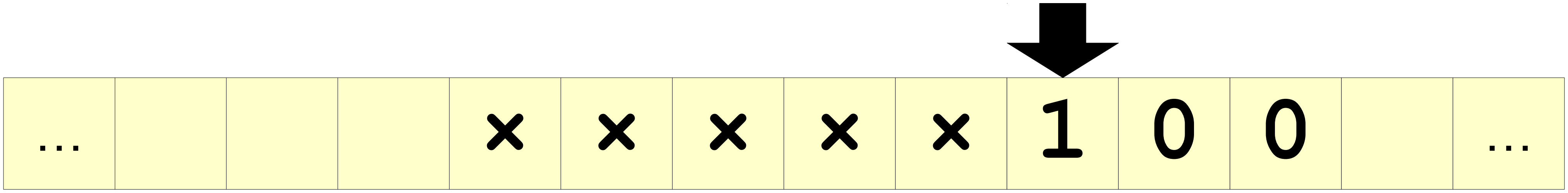
0 → 0, R
× → ×, R

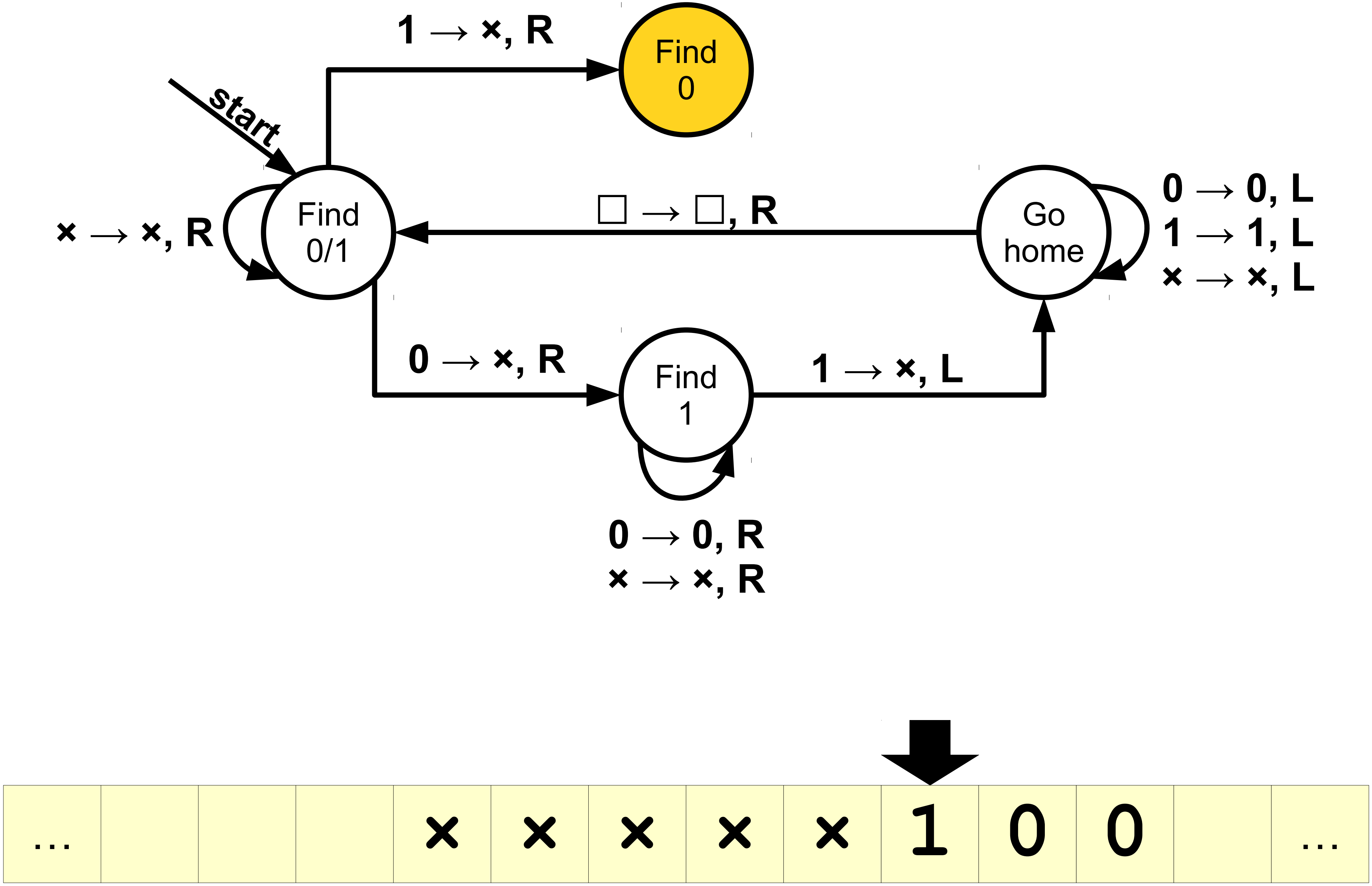
…				×	×	×	×	1	1	0	0		…



…				×	×	×	×	1	1	0	0		…


1 → ×, R
start
× → ×, R
Find 0/1
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R


…
×
×
×
×
×
1
0
0
…



start

Find 0/1

× → ×, R

1 → ×, R

Find 0

0 → ×, R

Find 1

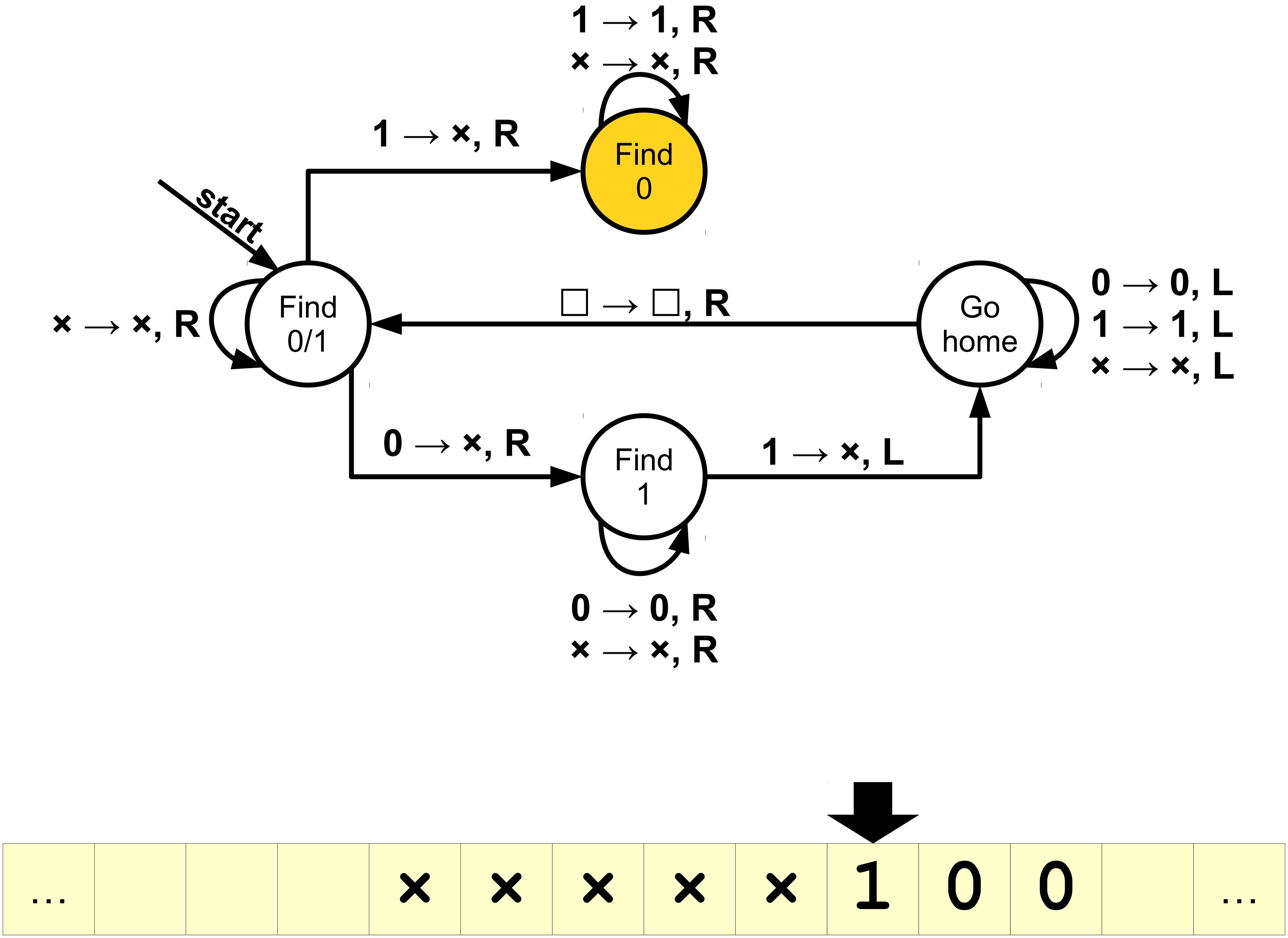
0 → 0, R
× → ×, R

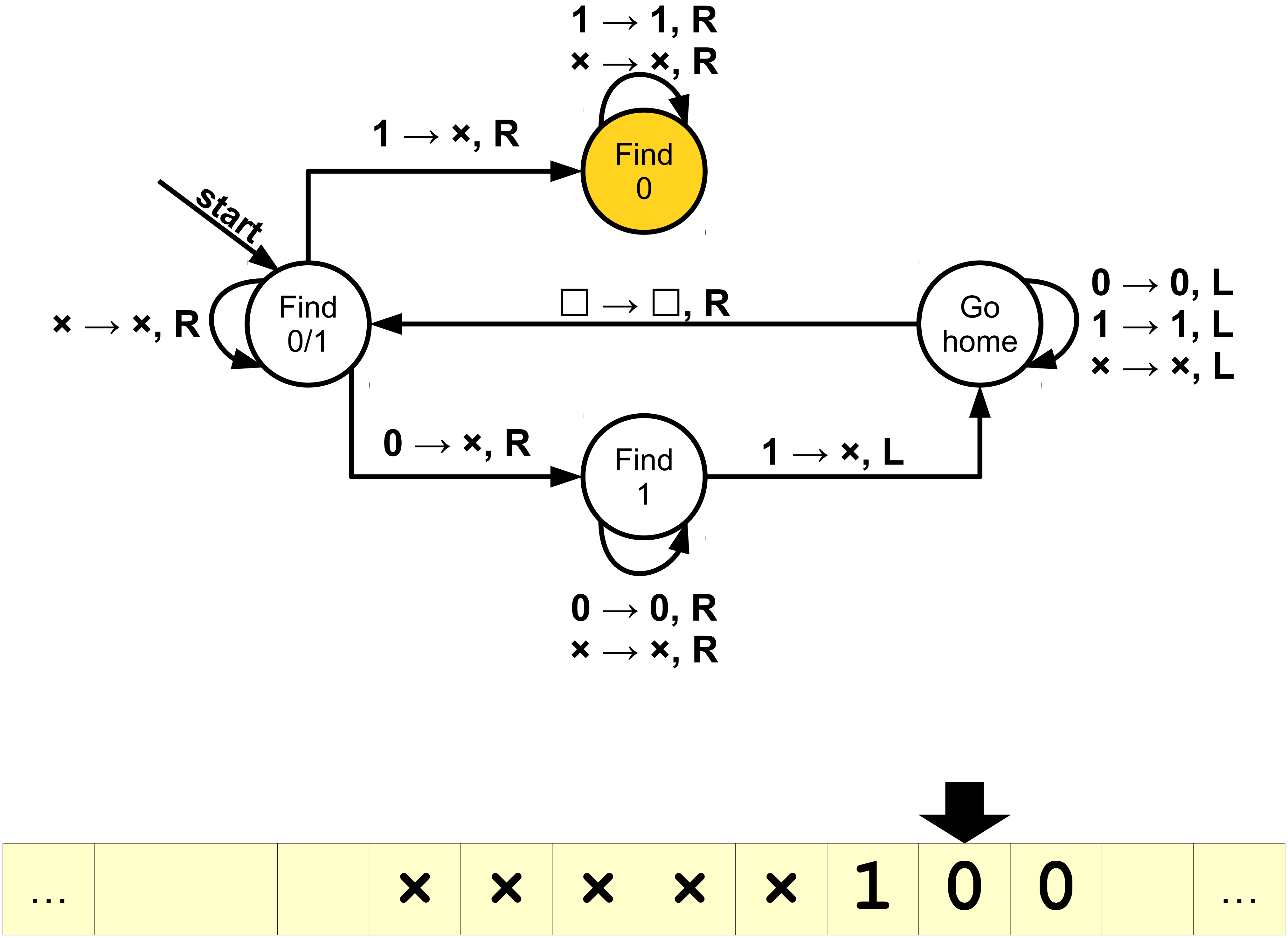
1 → ×, L

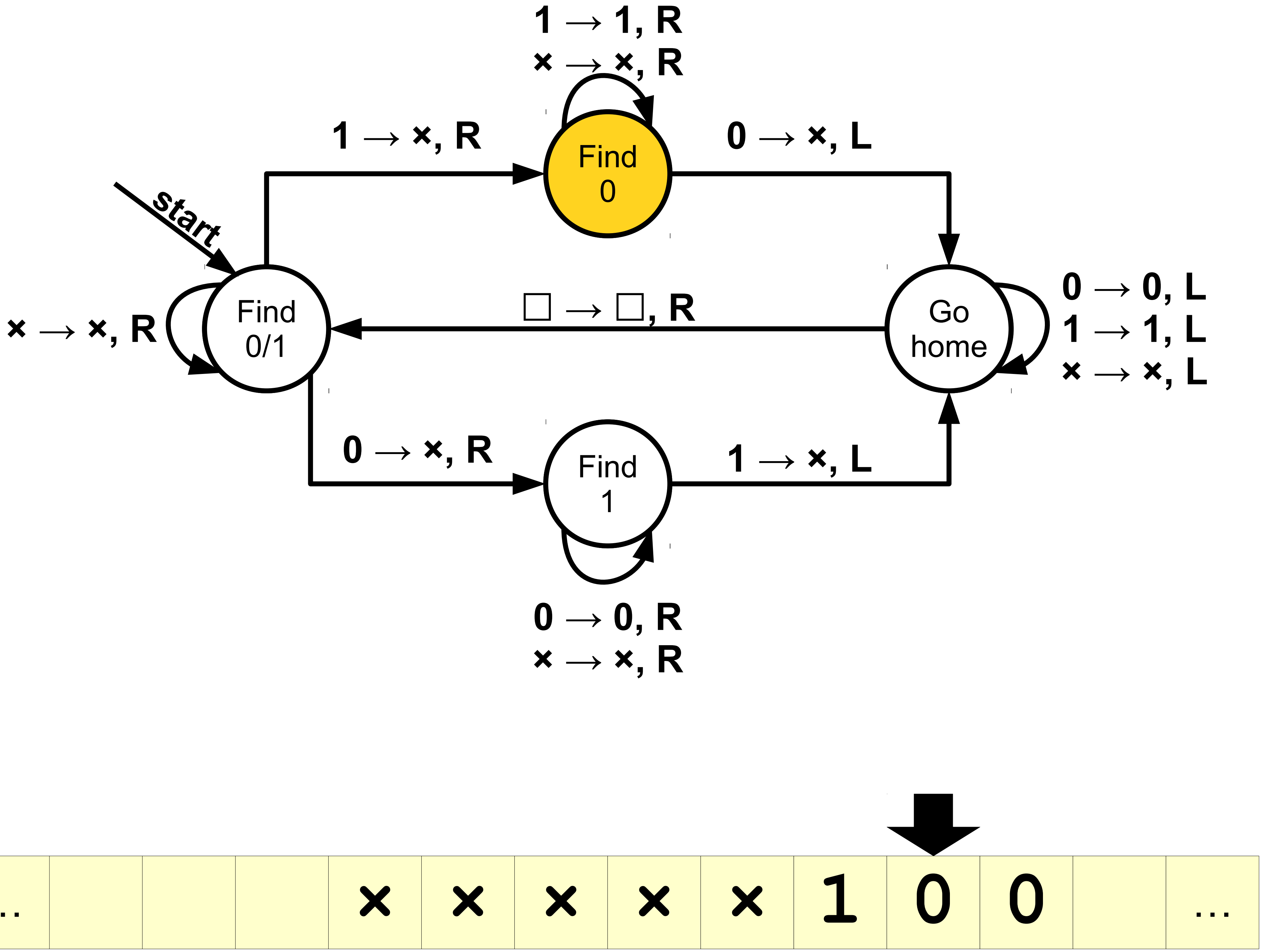
Go home

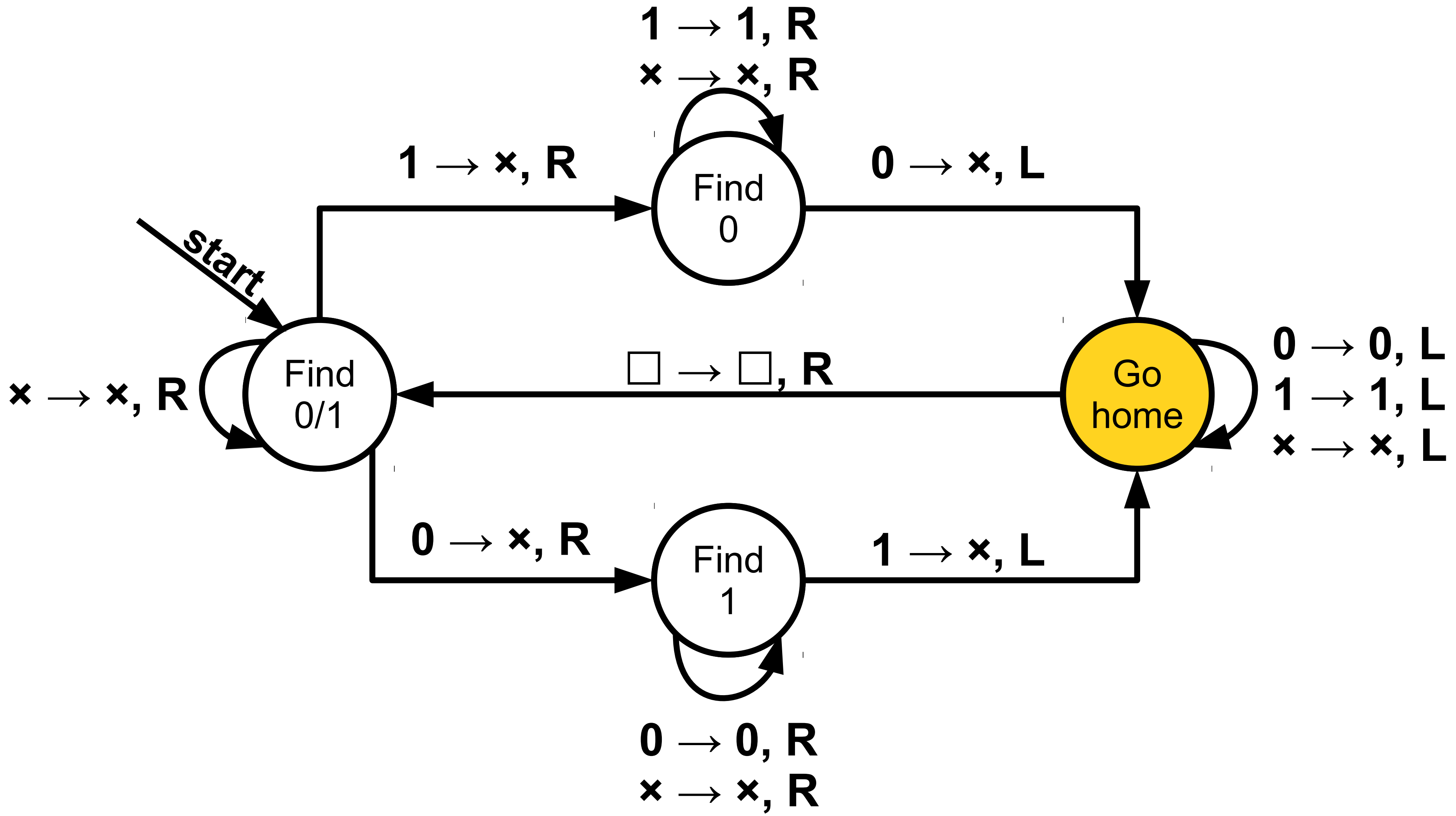
0 → 0, L
1 → 1, L
× → ×, L

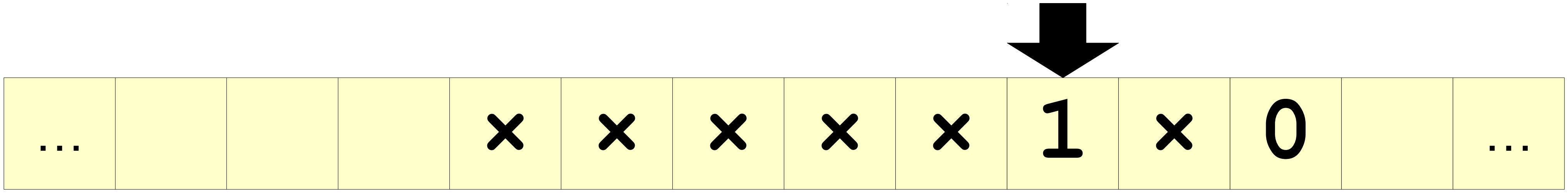
□ → □, R


1 → 1, R
× → ×, R
1 → ×, R
Find
0
start
× → ×, R
Find
0/1
□ → □, R
Go
home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find
1
1 → ×, L
0 → 0, R
× → ×, R
…
×
×
×
×
×
1
0
0
…

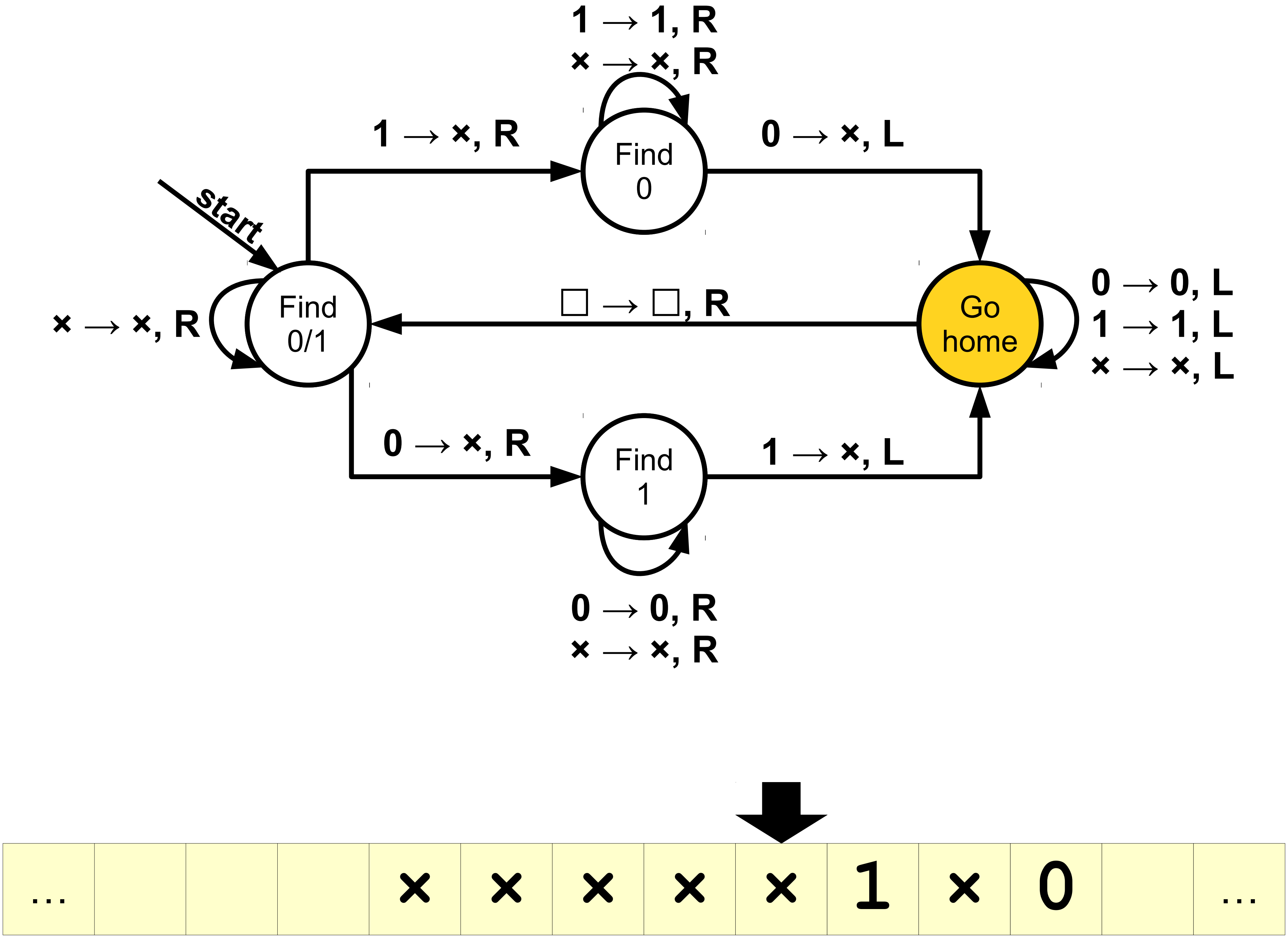

1 → 1, R
× → ×, R
1 → ×, R
Find 0
start
× → ×, R
Find 0/1
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R
…
×
×
×
×
×
1
0
0
…


start
Find 0/1
× → ×, R
1 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
0 → ×, R
Find 1
0 → 0, R
× → ×, R
1 → ×, L
…
×
×
×
×
×
1
0
0
…

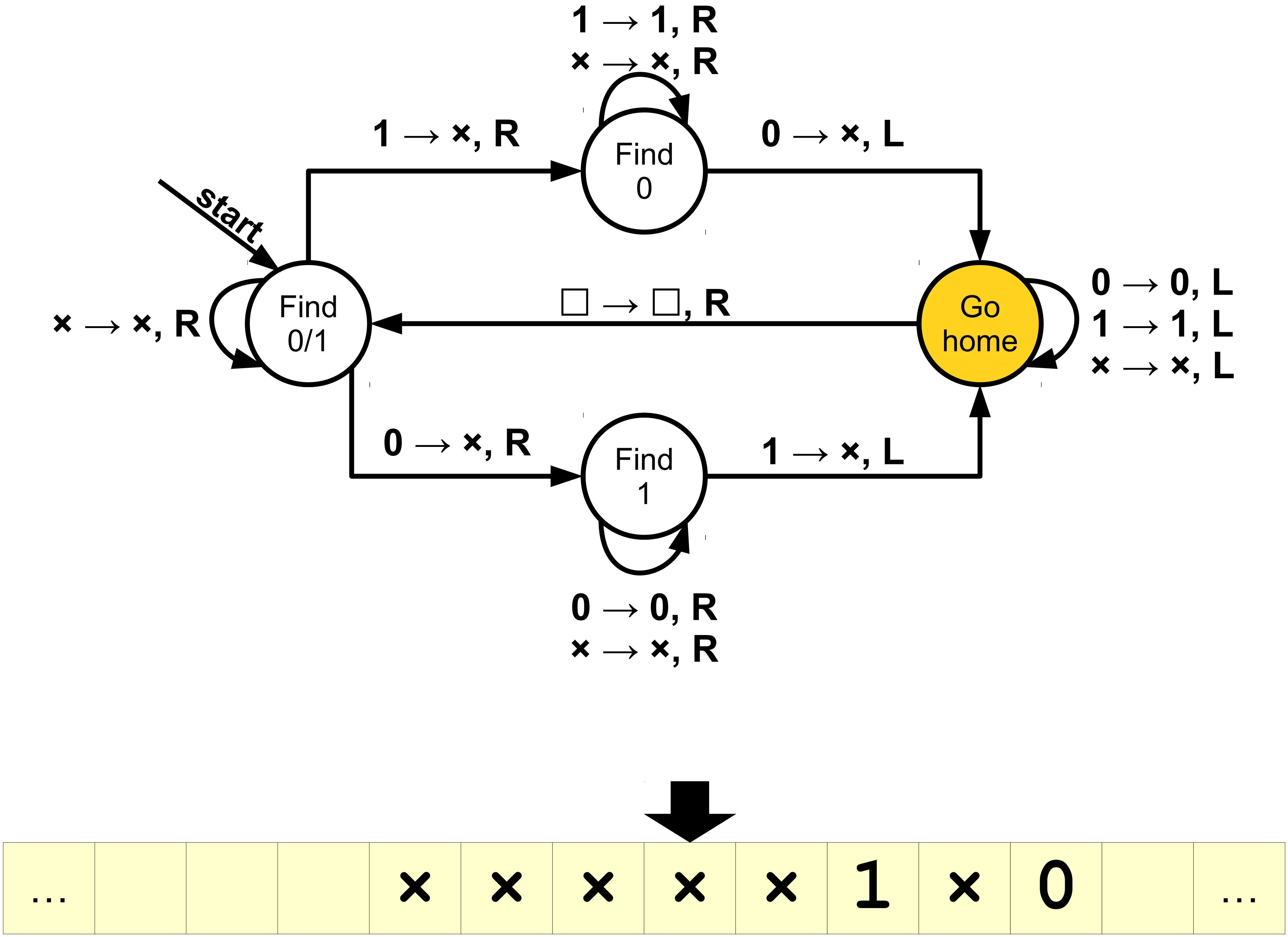

1 → 1, R
× → ×, R
1 → ×, R
0 → ×, L
start
Find 0/1
× → ×, R
Find 0
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R

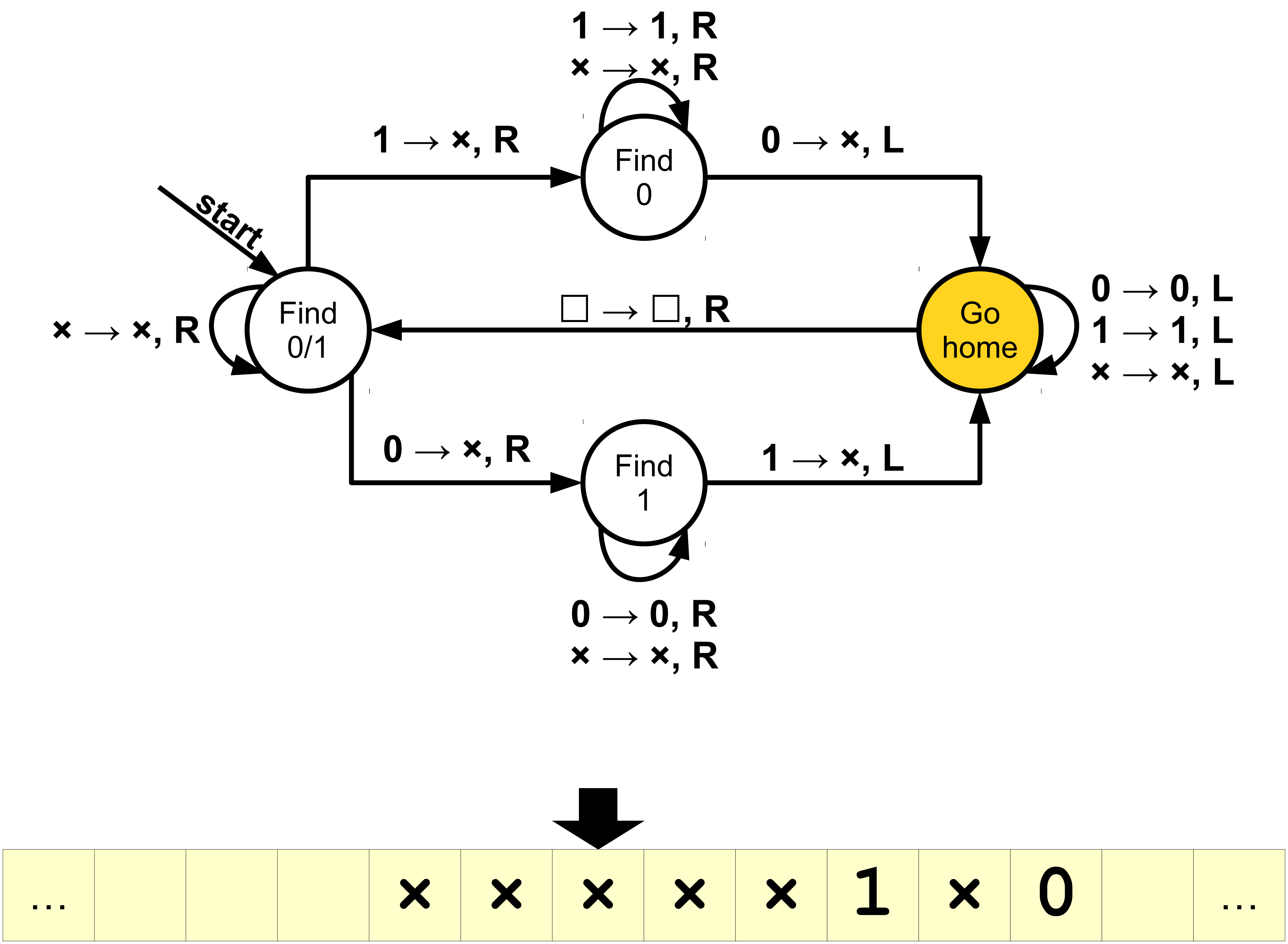


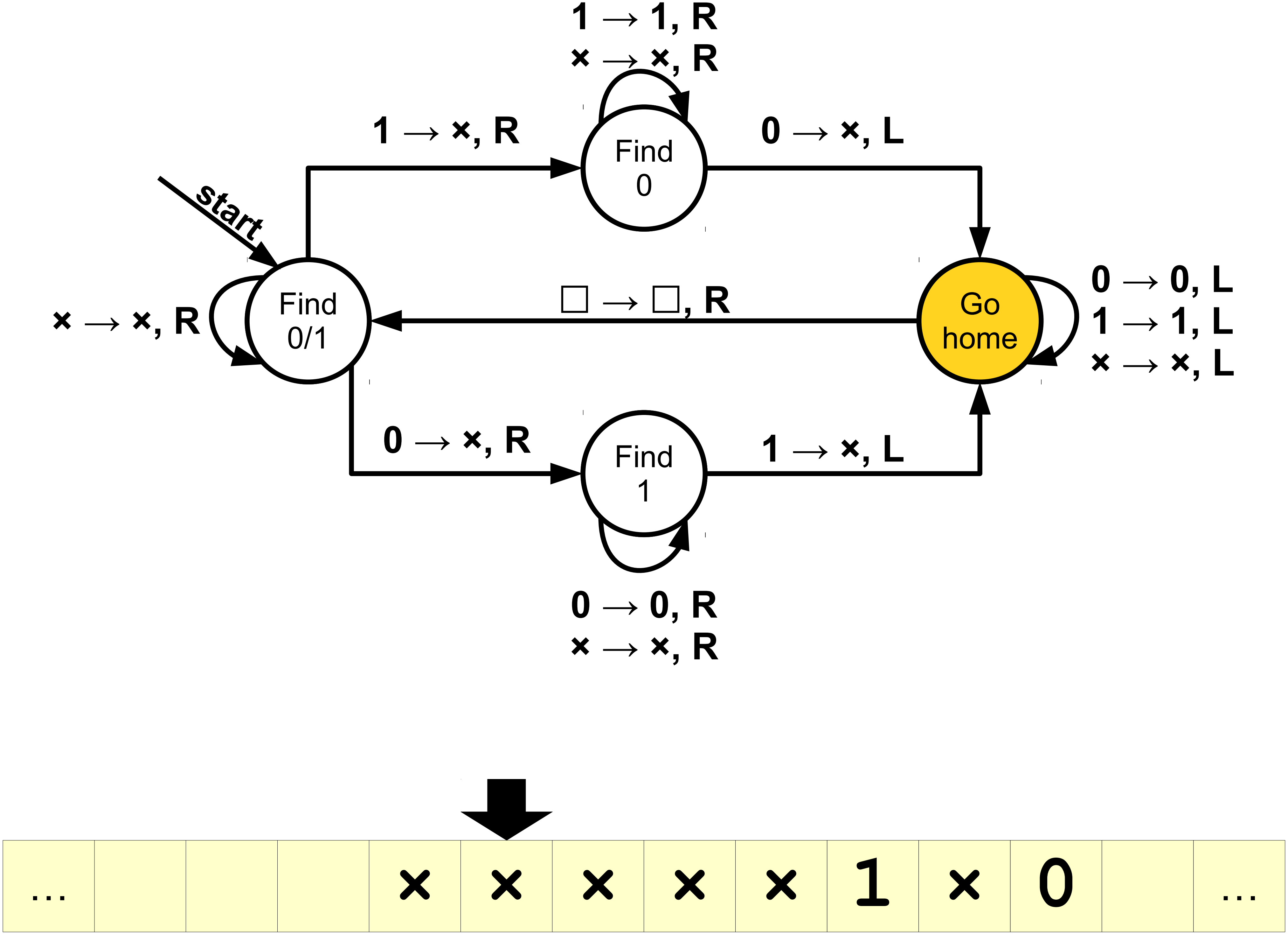
…				×	×	×	×	×	1	×	0		…

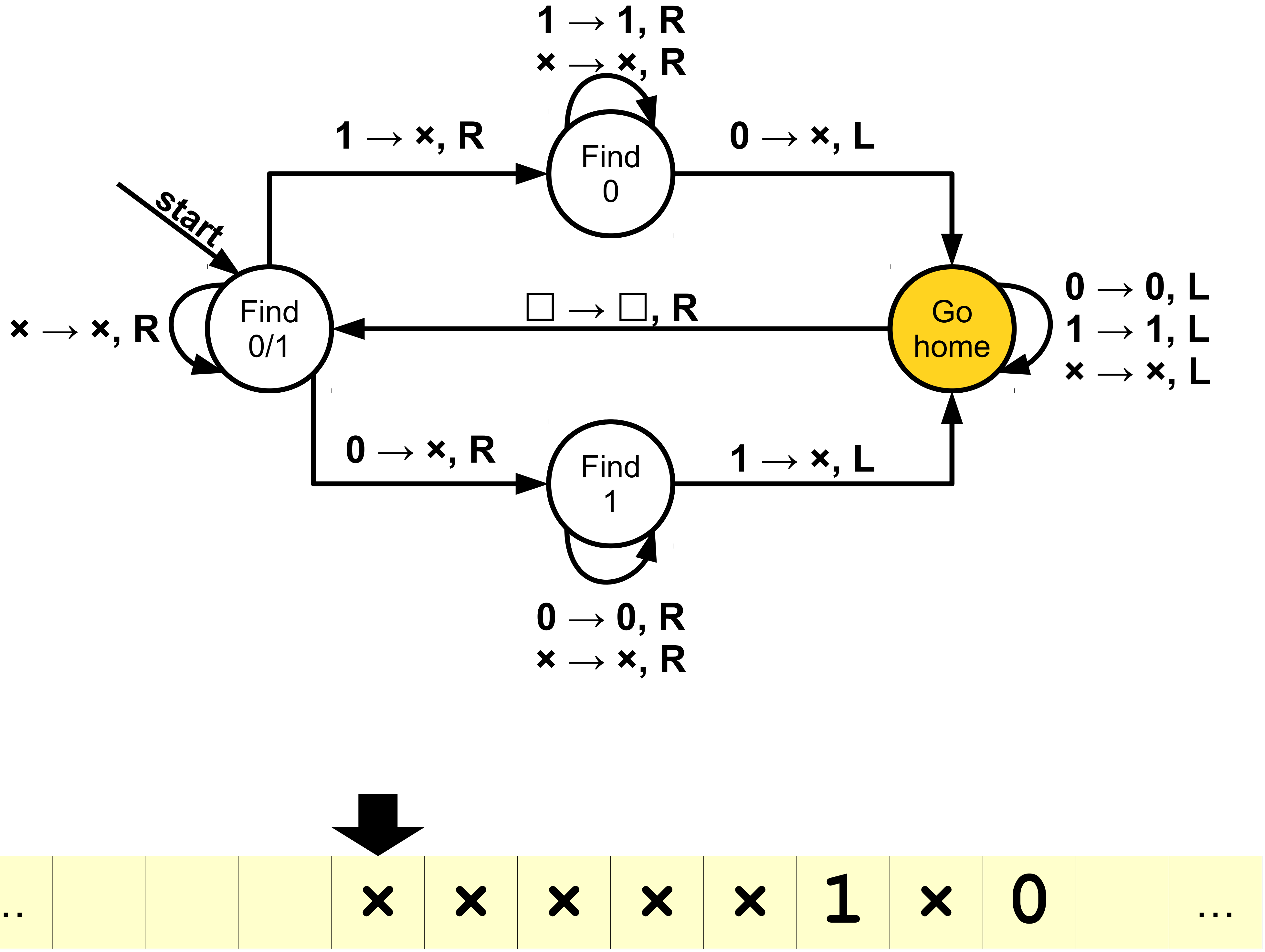

start
Find 0/1
× → ×, R
1 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
0 → ×, R
Find 1
0 → 0, R
× → ×, R
1 → ×, L

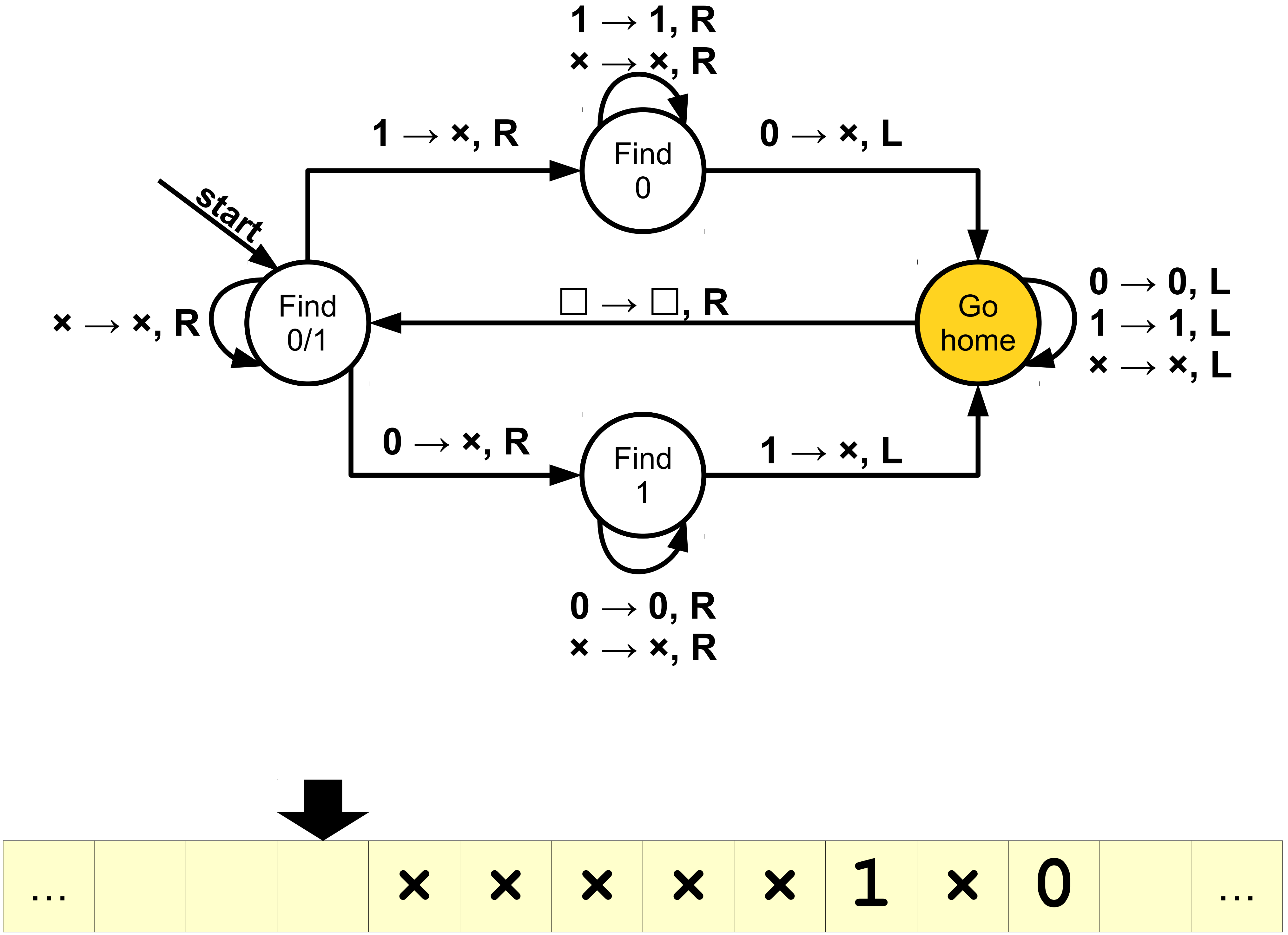
…				×	×	×	×	×	1	×	0		…

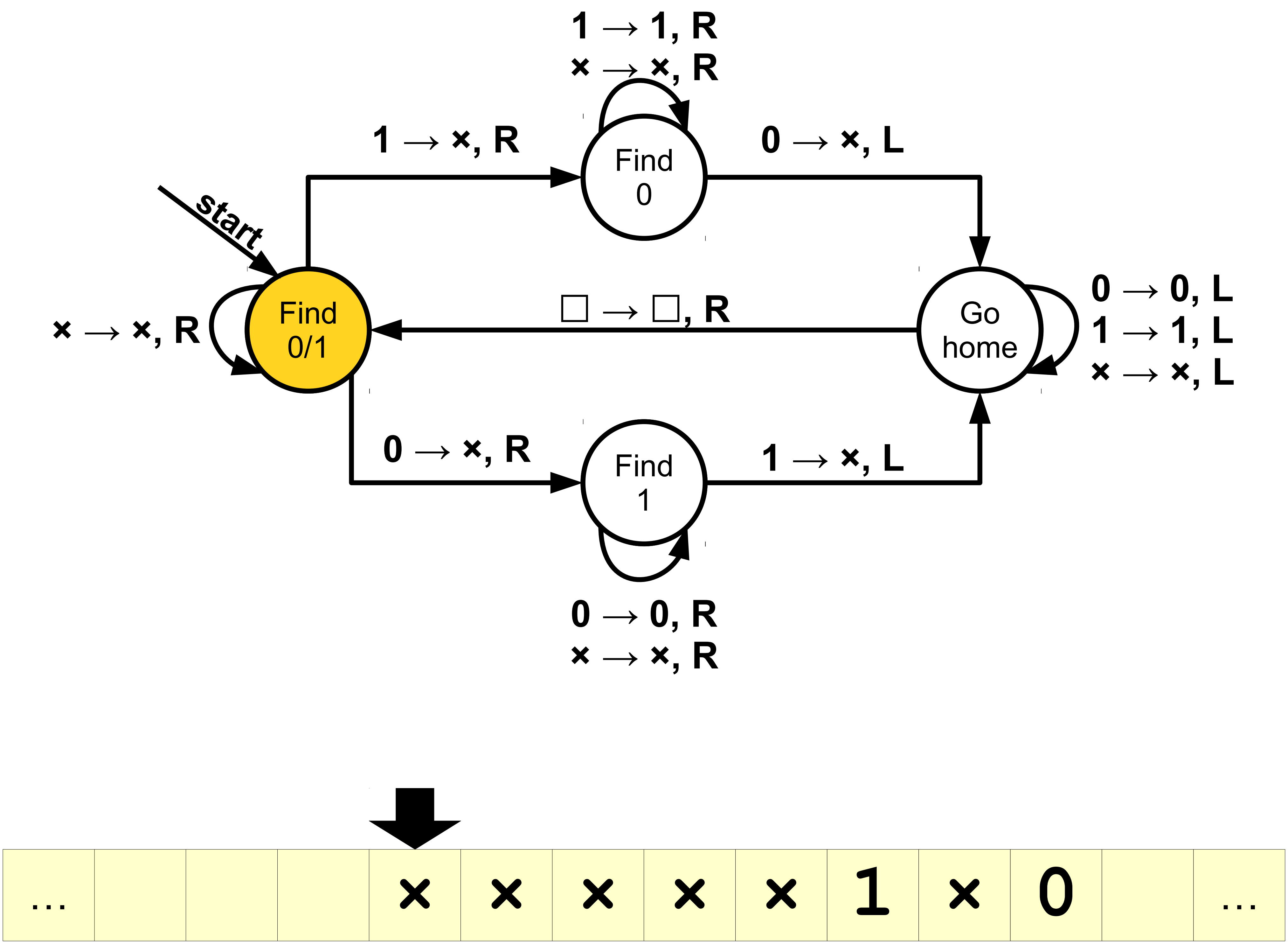

1 → 1, R
× → ×, R
1 → ×, R
Find 0
0 → ×, L
start
Find 0/1
× → ×, R
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R
…
×
×
×
×
×
1
×
0
…

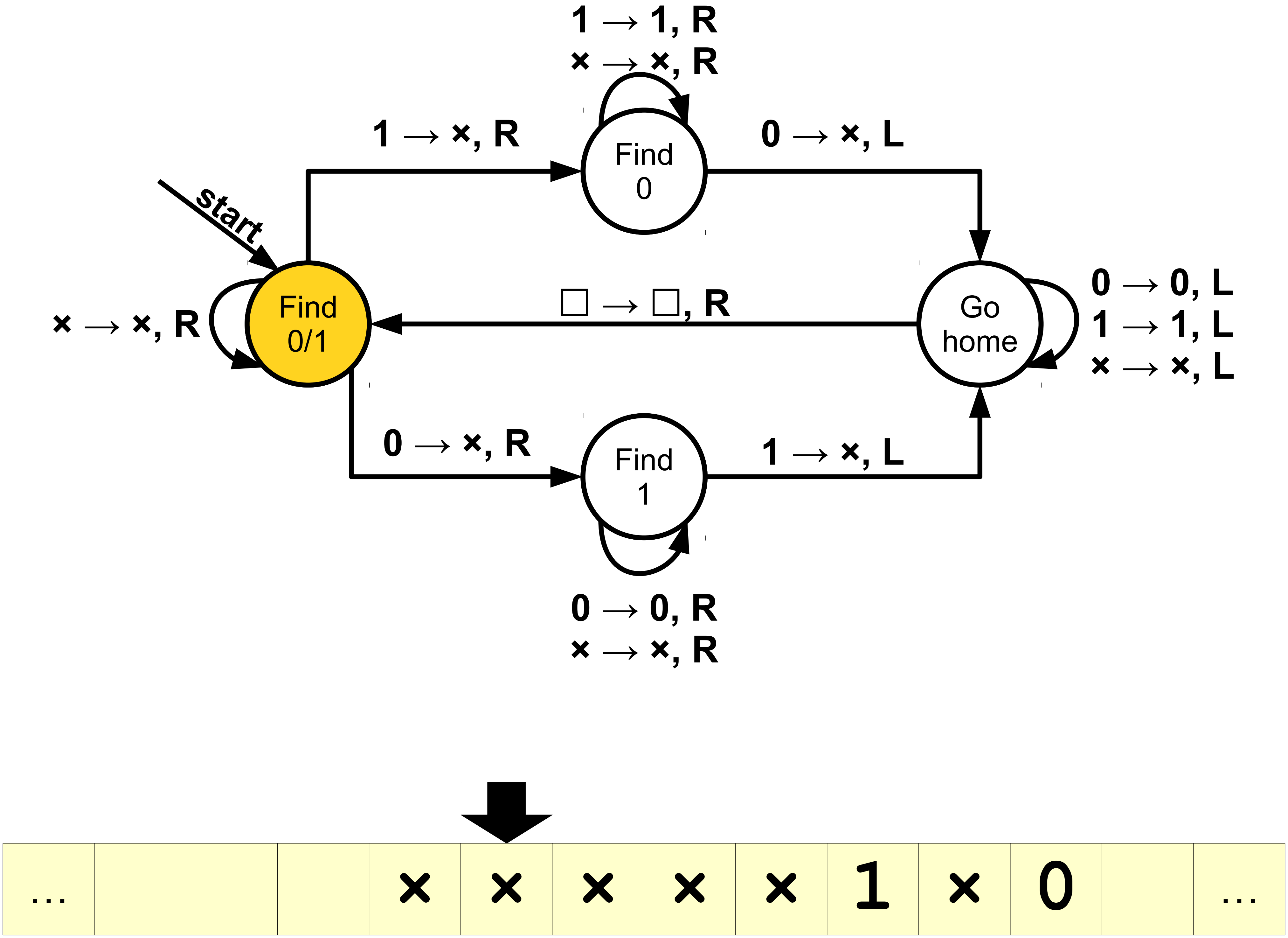

1 → 1, R
× → ×, R
1 → ×, R
0 → ×, L
start
Find 0
Find 0/1
× → ×, R
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R
…
×
×
×
×
×
1
×
0
…

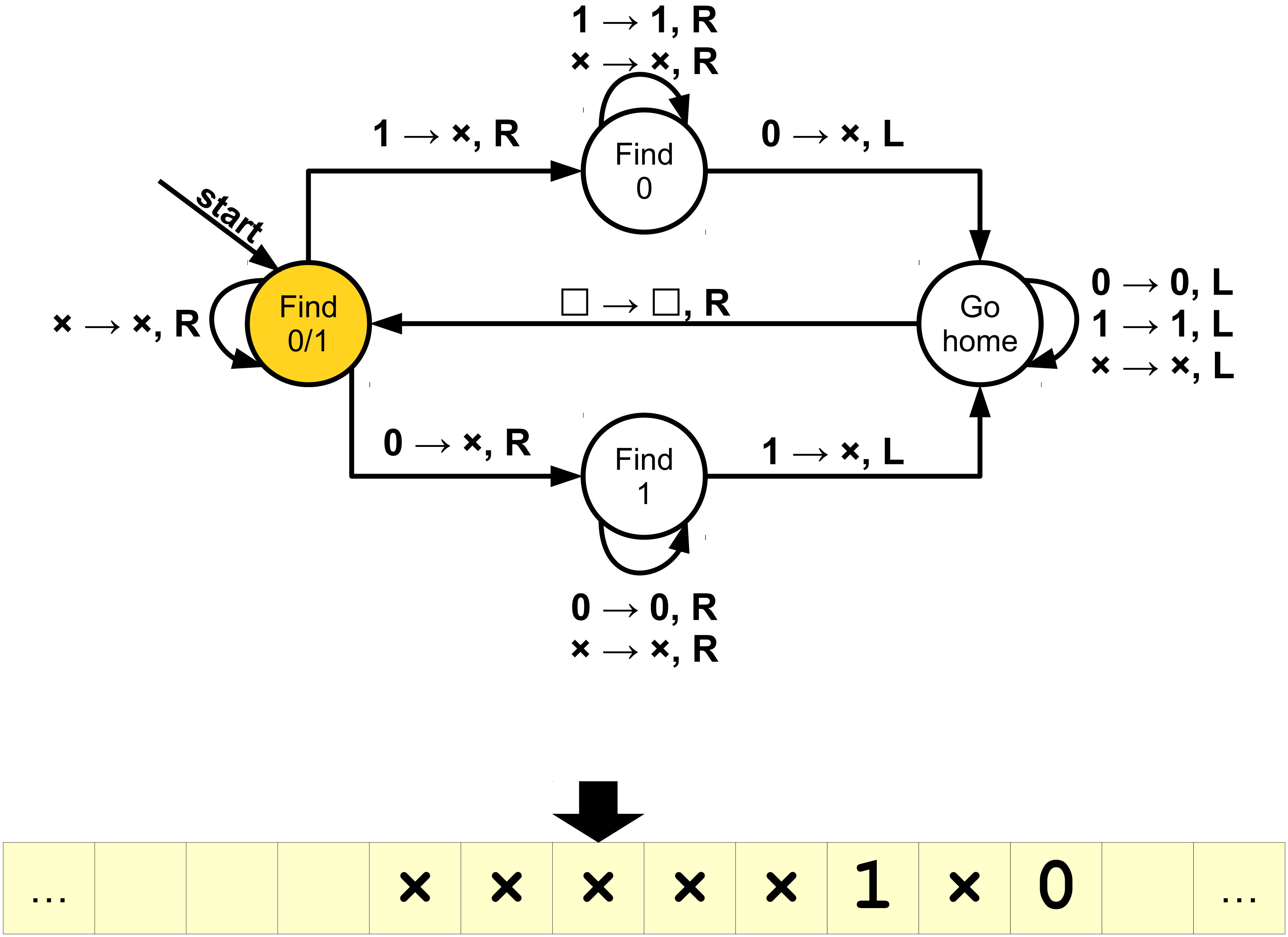

1 → 1, R
× → ×, R
1 → ×, R
Find 0
0 → ×, L
start
Find 0/1
× → ×, R
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R
…
×
×
×
×
×
1
×
0
…

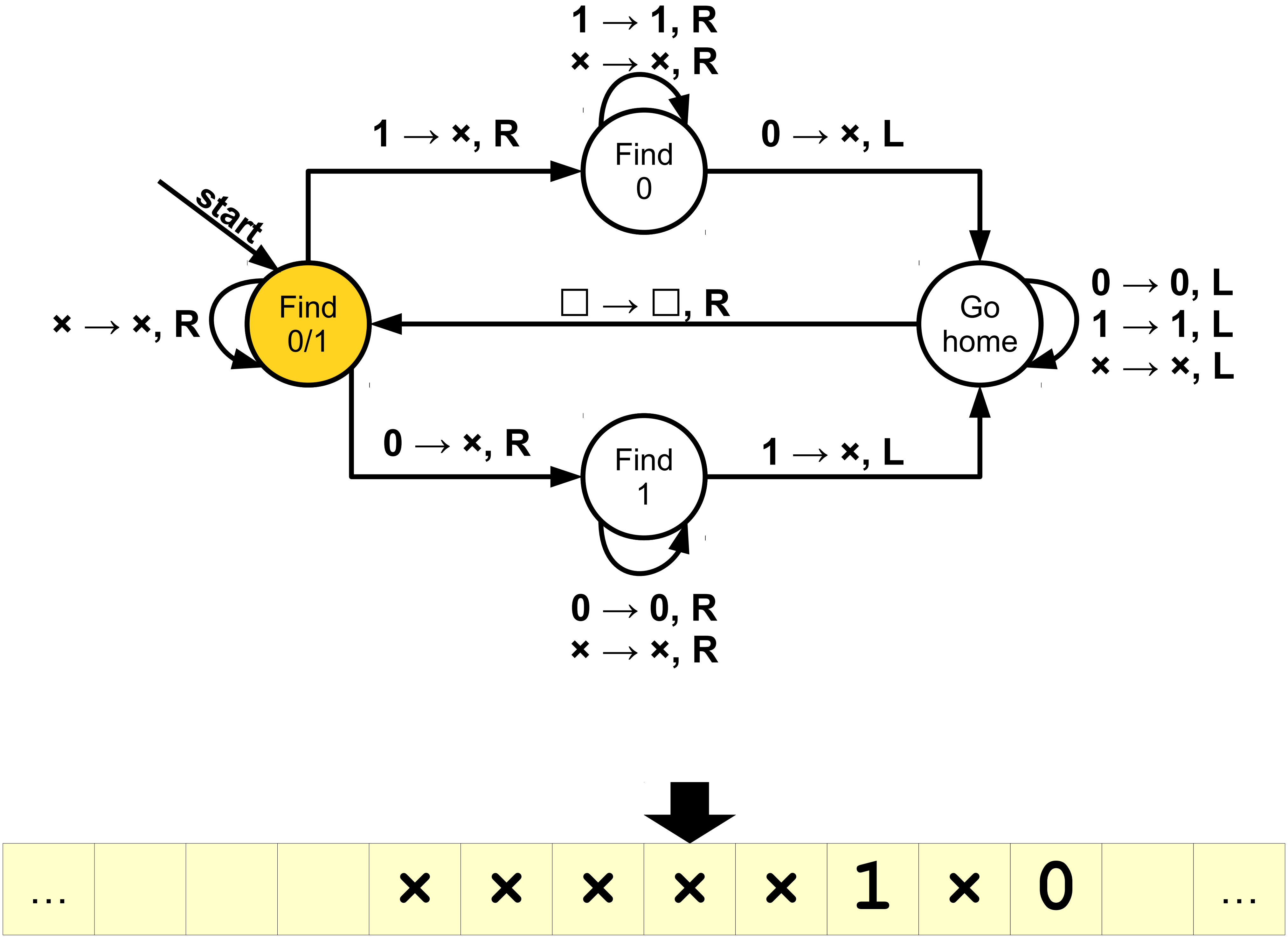

1 → 1, R
× → ×, R
1 → ×, R
0 → ×, L
start
Find 0
× → ×, R
Find 0/1
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R
…
×
×
×
×
×
1
×
0
…

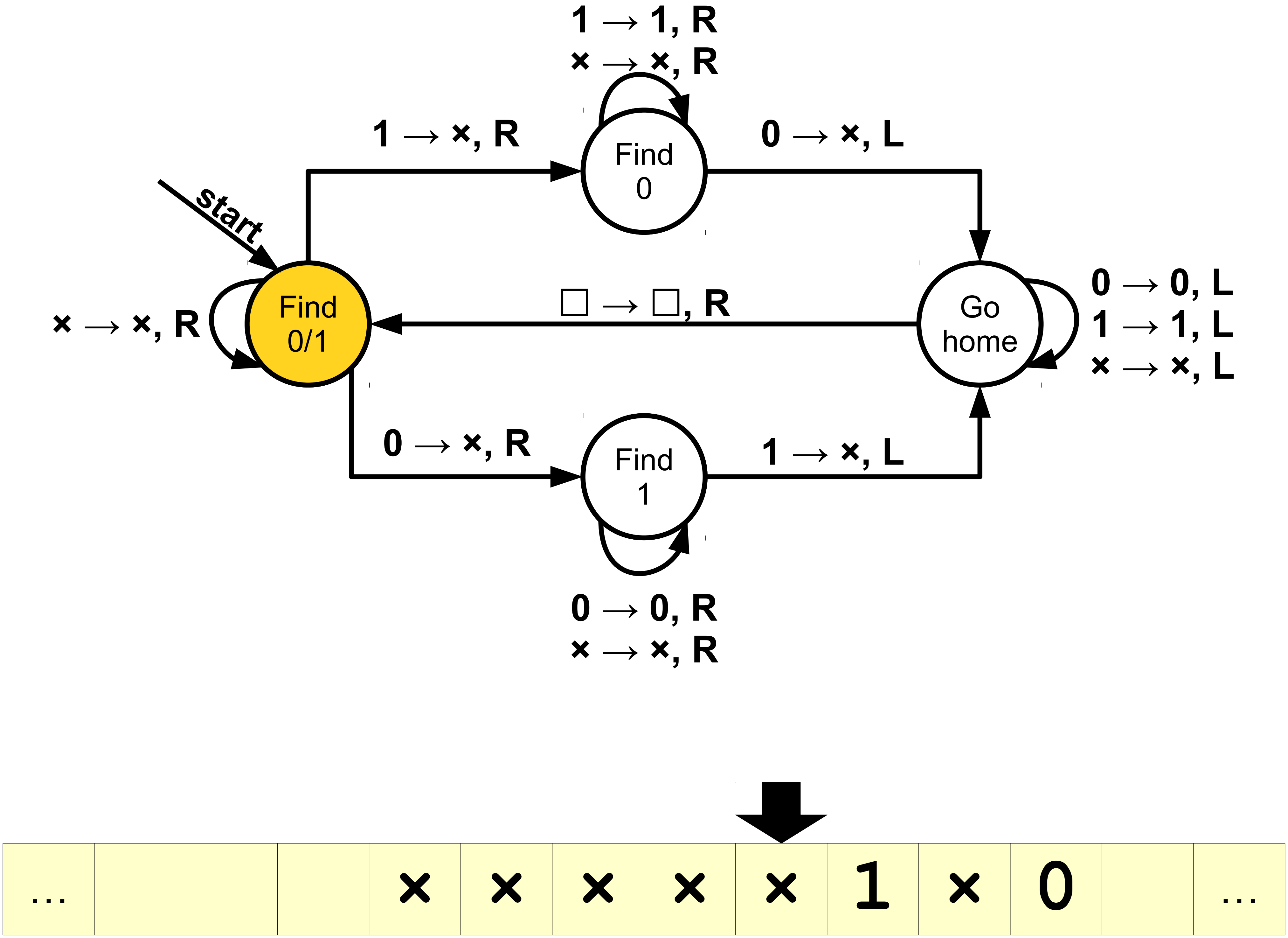

start
Find 0/1
× → ×, R
1 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
0 → ×, R
Find 1
0 → 0, R
× → ×, R
1 → ×, L
…
×
×
×
×
×
1
×
0
…

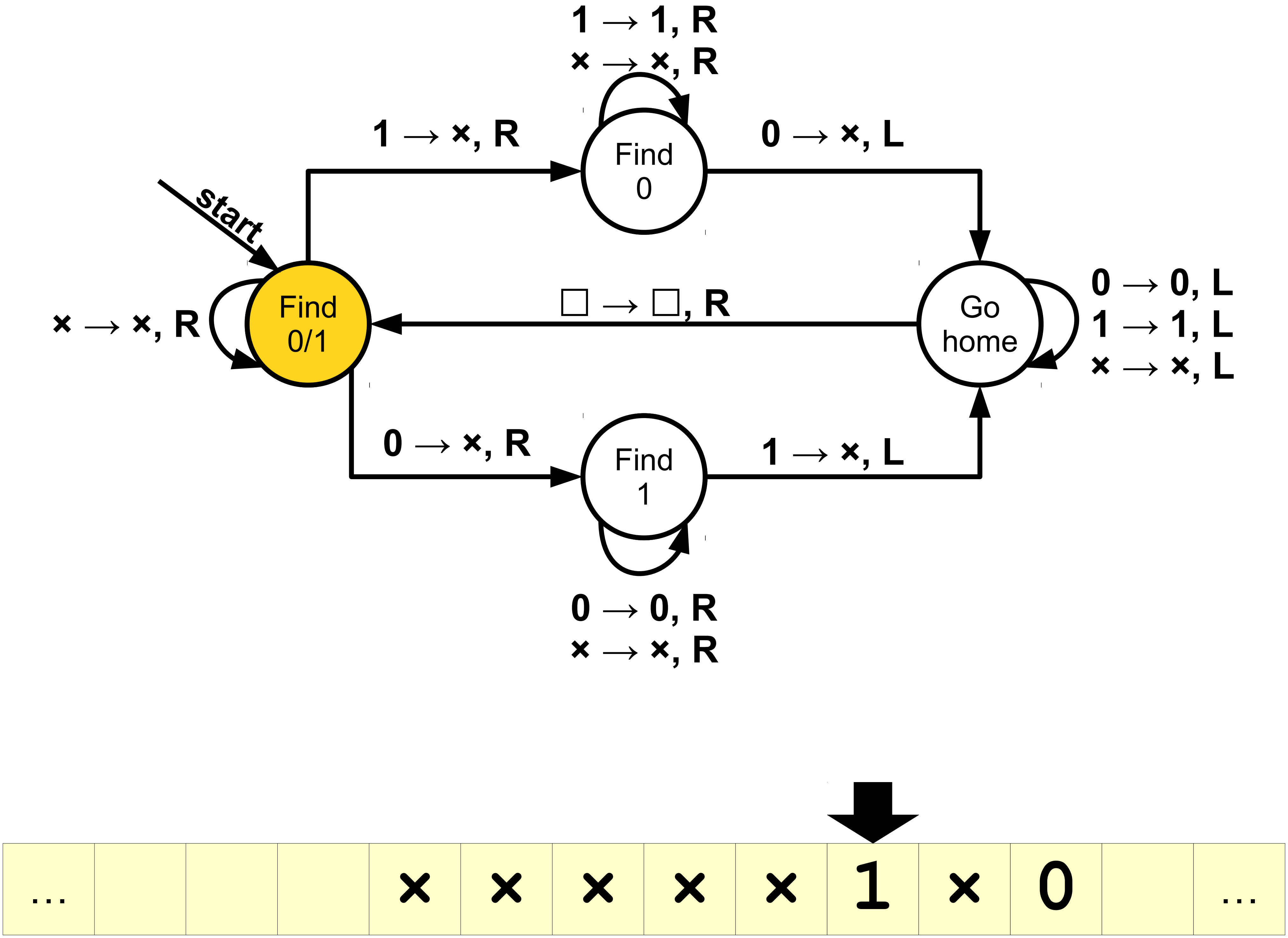

start
Find 0/1
× → ×, R
1 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
0 → ×, R
Find 1
0 → 0, R
× → ×, R
1 → ×, L
… × × × × × 1 × 0 …

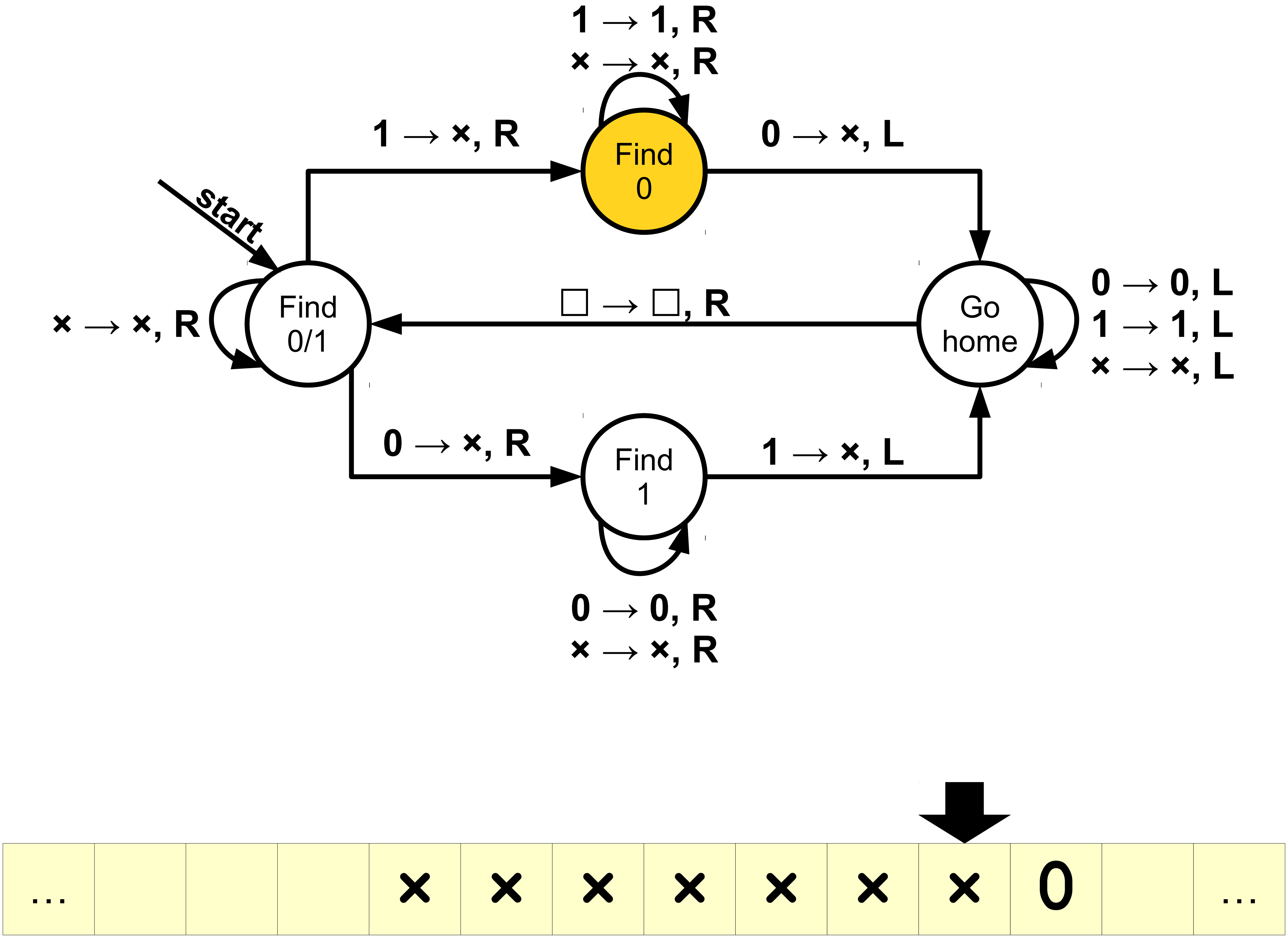

start
Find 0/1
× → ×, R
1 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
0 → ×, R
Find 1
0 → 0, R
× → ×, R
1 → ×, L
…
×
×
×
×
×
1
×
0
…

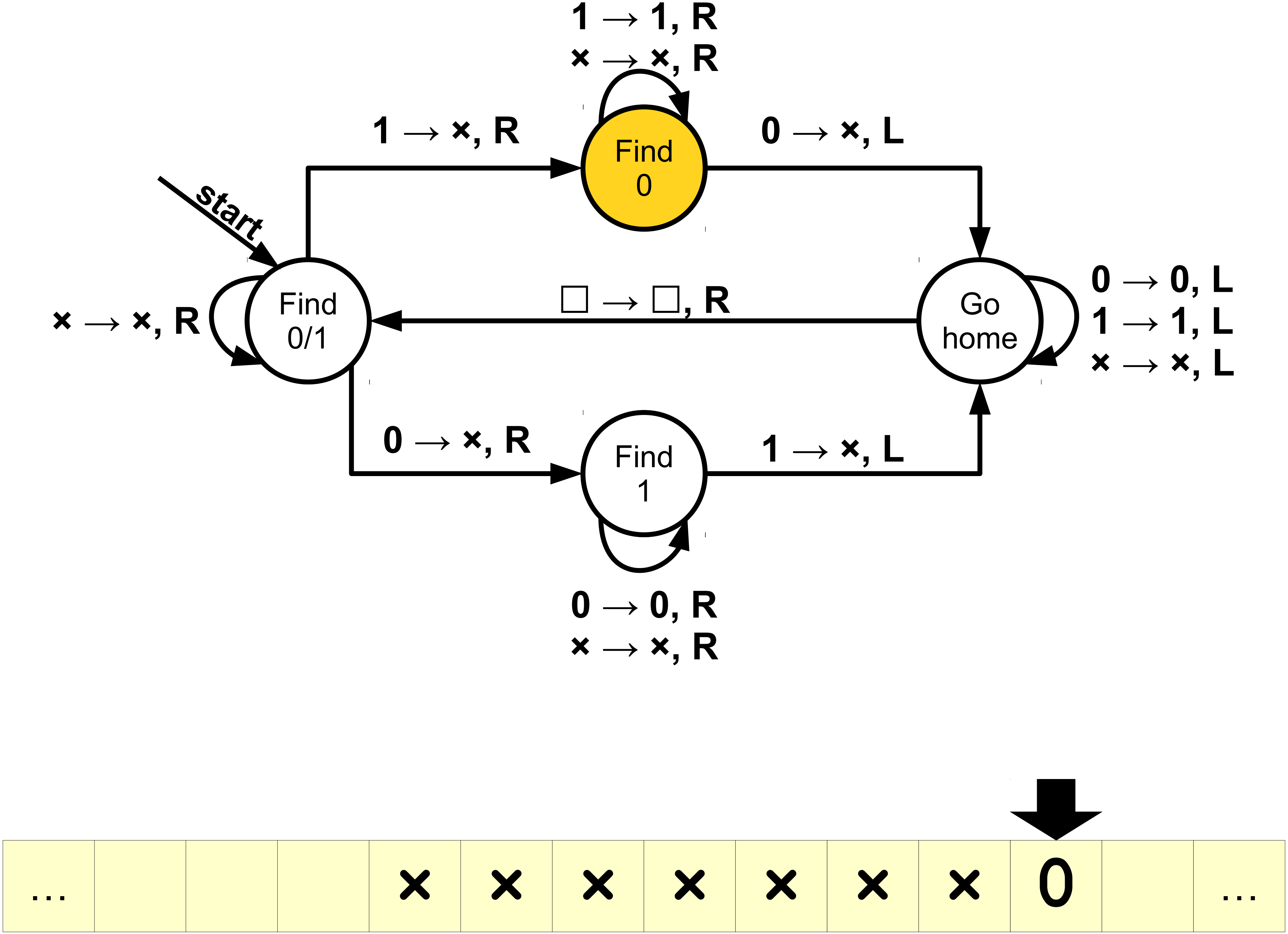

start
Find 0/1
× → ×, R
1 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
0 → 0, R
× → ×, R
1 → ×, L
…
×
×
×
×
×
1
×
0
…

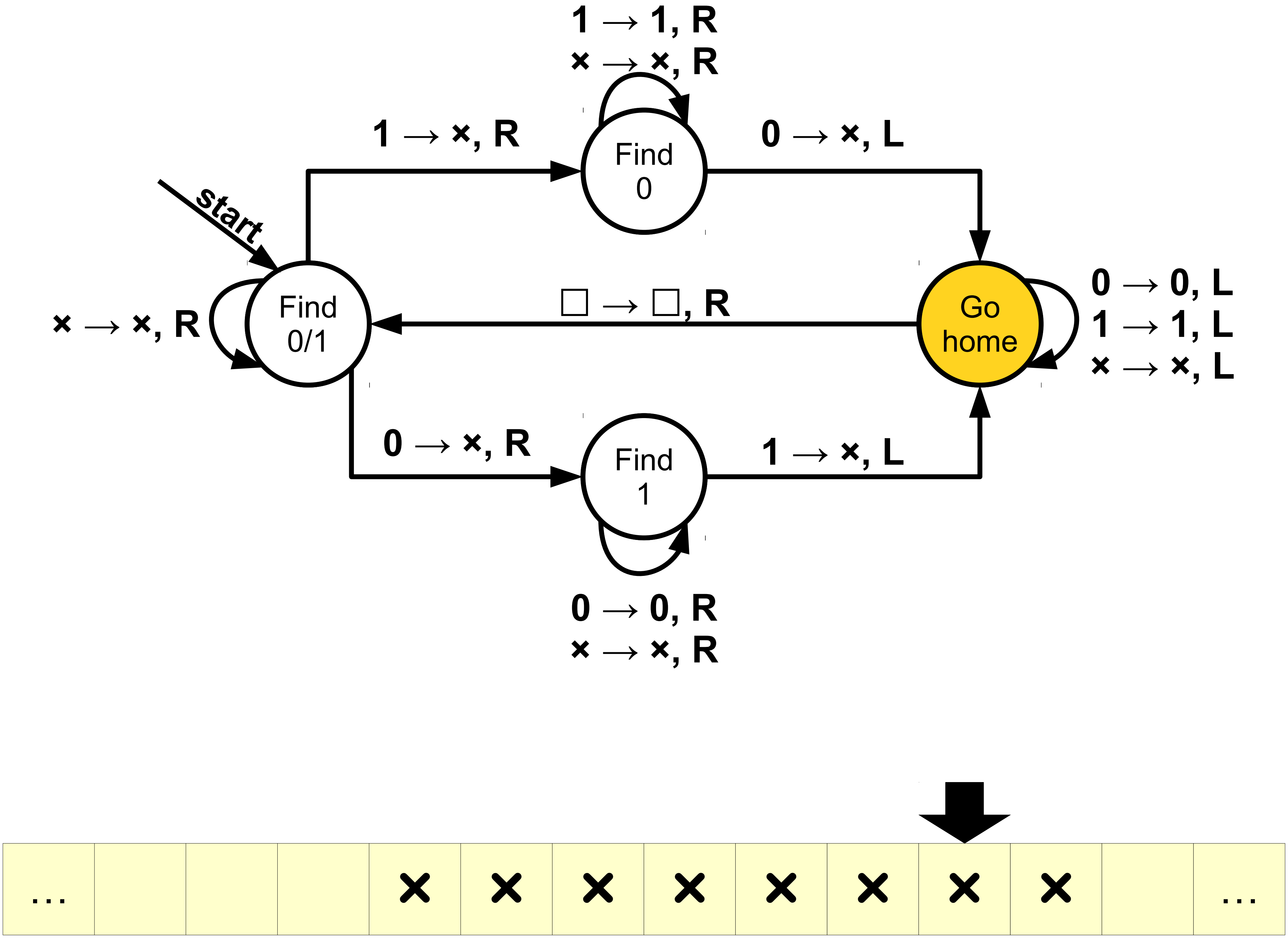

1 → 1, R
× → ×, R
1 → ×, R
0 → ×, L
start
Find 0
Find 0/1
× → ×, R
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R
…
×
×
×
×
×
1
×
0
…

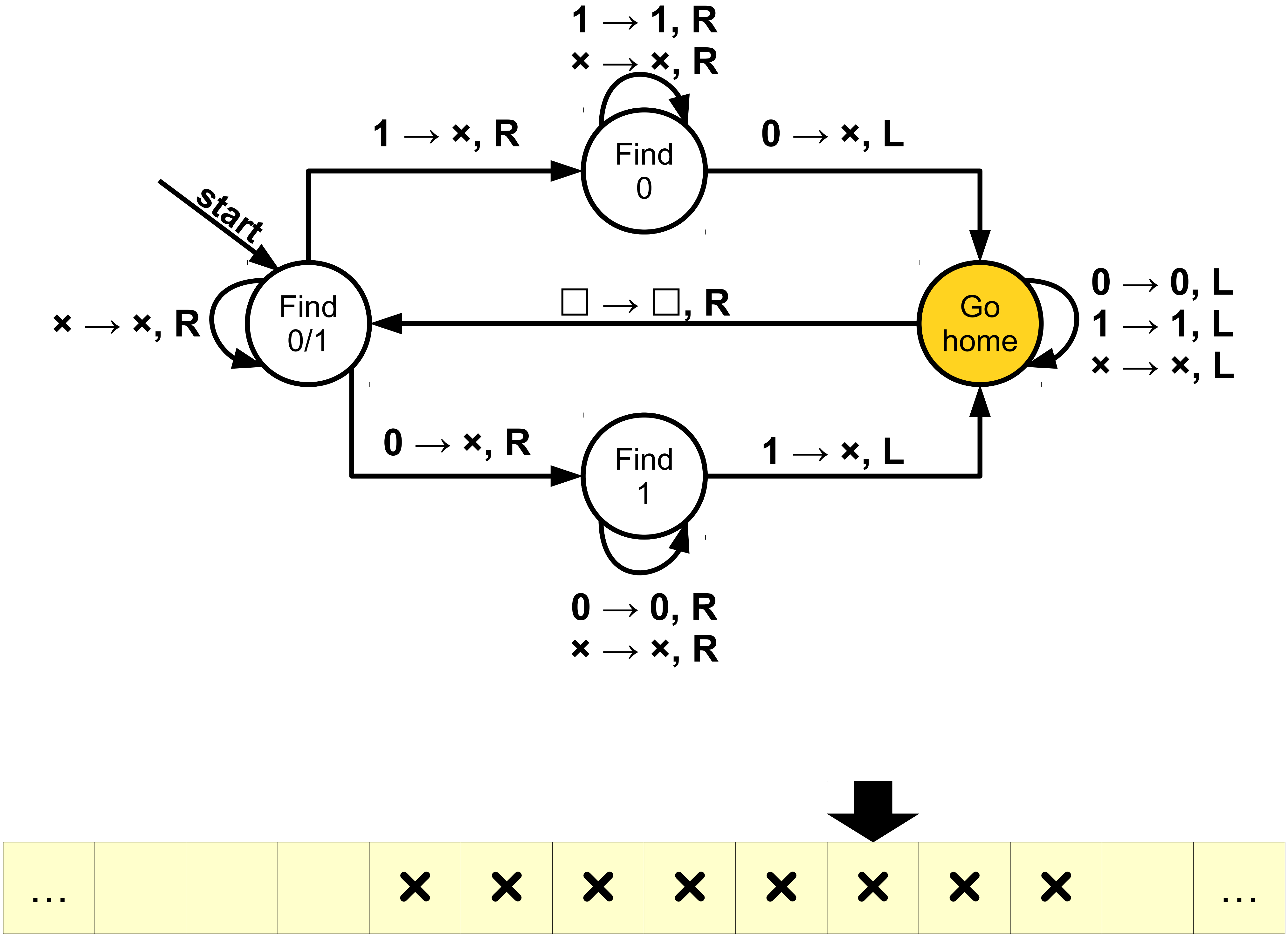

1 → 1, R
× → ×, R
1 → ×, R
Find 0
0 → ×, L
start
Find 0/1
× → ×, R
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R
…
×
×
×
×
×
1
×
0
…

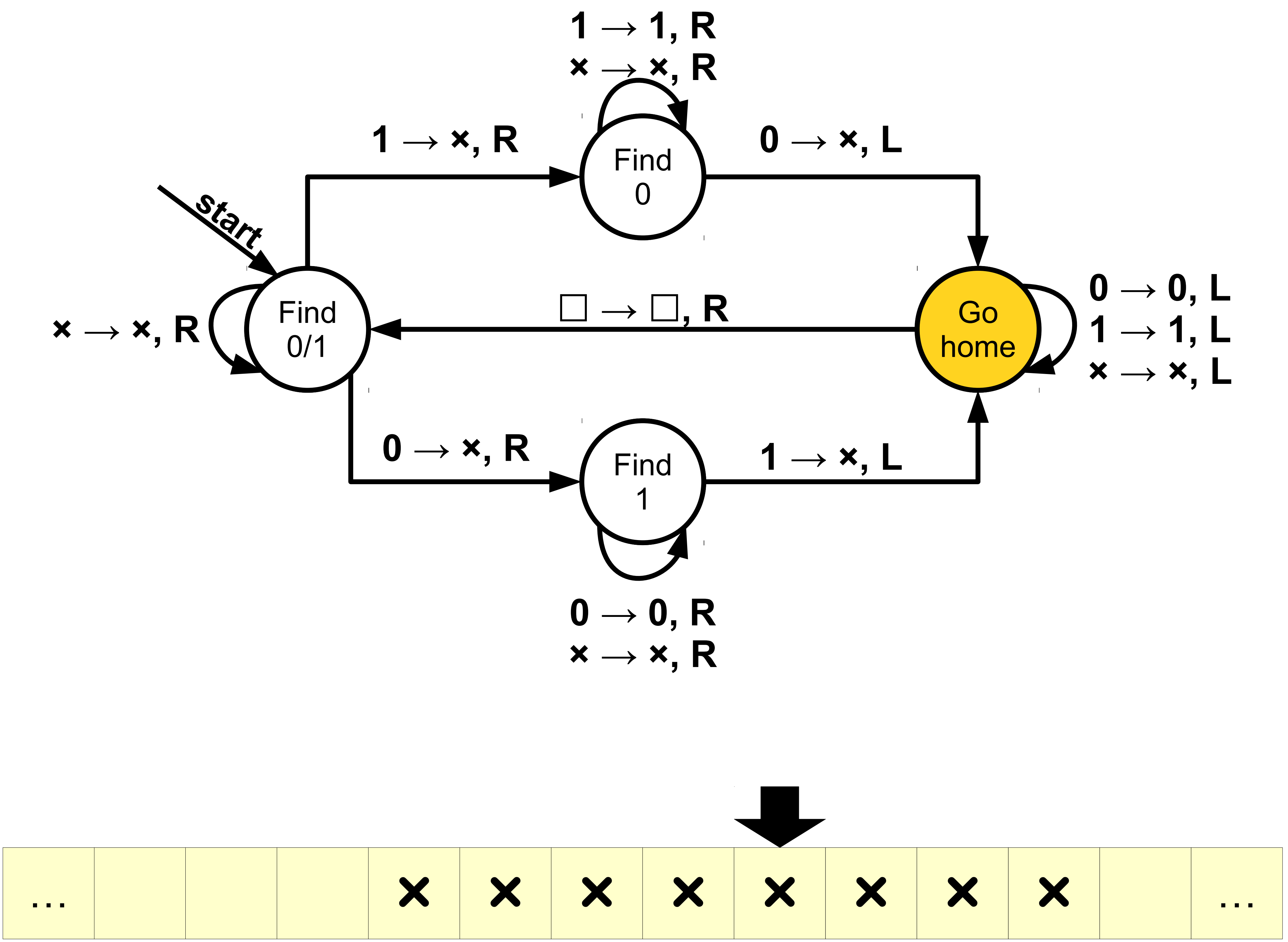

start
Find 0/1
× → ×, R
1 → ×, R
0 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
Find 1
0 → 0, R
× → ×, R
1 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
…
×
×
×
×
×
1
×
0
…

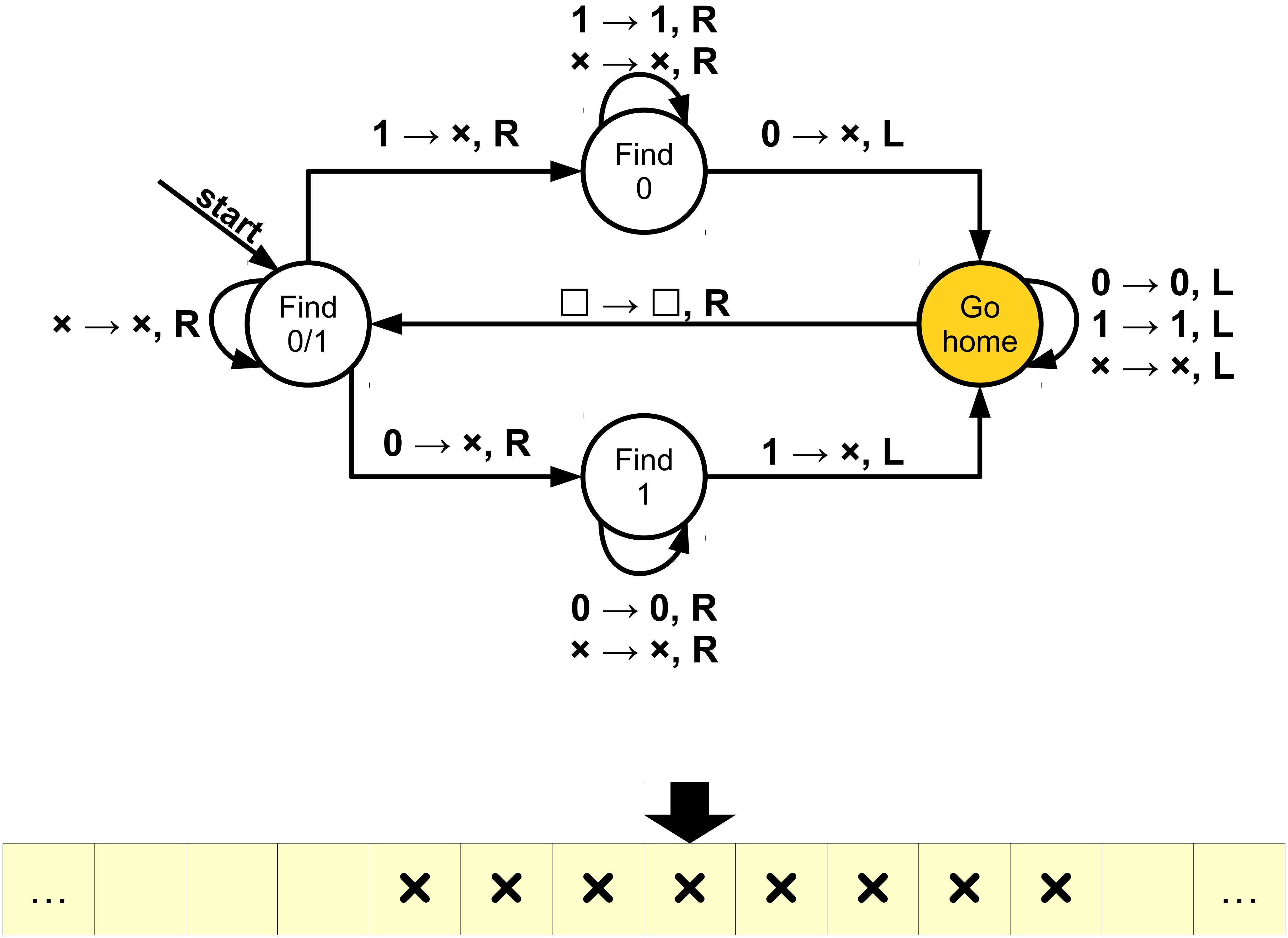

start
Find 0/1
× → ×, R
1 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
0 → ×, R
Find 1
0 → 0, R
× → ×, R
1 → ×, L
…
×
×
×
×
×
×
×
0
…

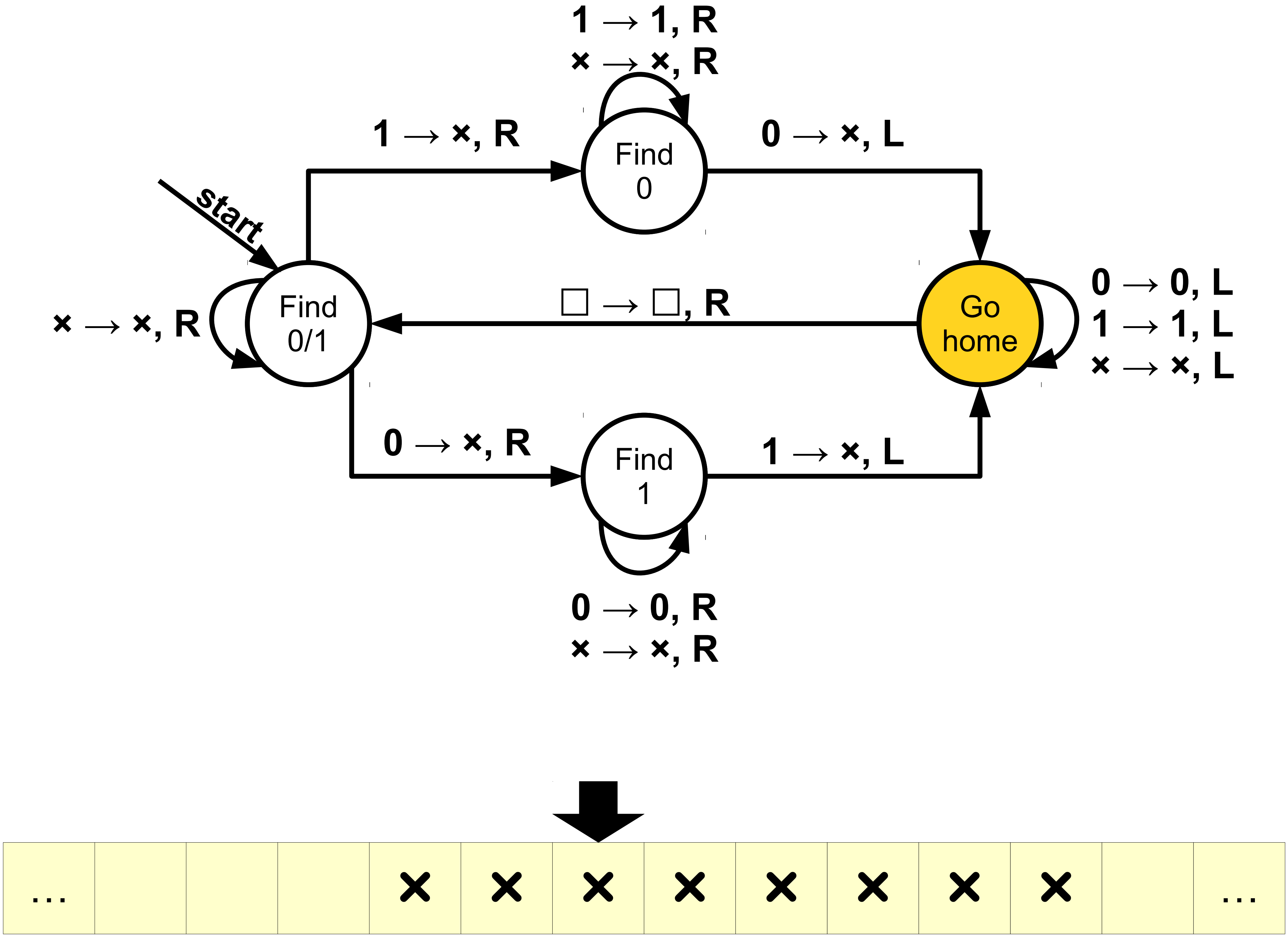

start
Find 0/1
× → ×, R
1 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
0 → ×, R
Find 1
0 → 0, R
× → ×, R
1 → ×, L
…
×
×
×
×
×
×
×
0
…

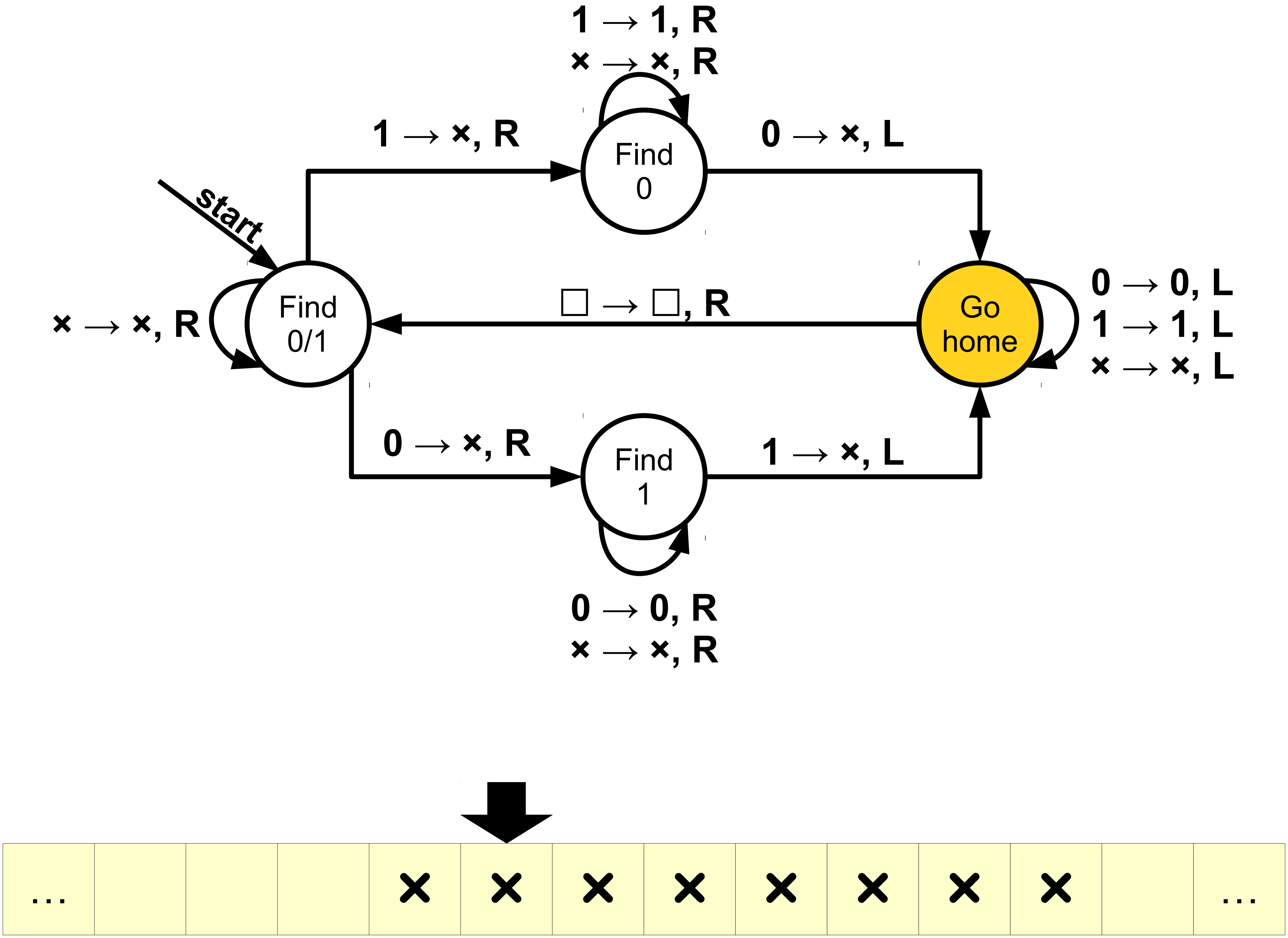

start
Find 0/1
× → ×, R
1 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
0 → ×, R
Find 1
0 → 0, R
× → ×, R
1 → ×, L
…
×
×
×
×
×
×
×
×
…

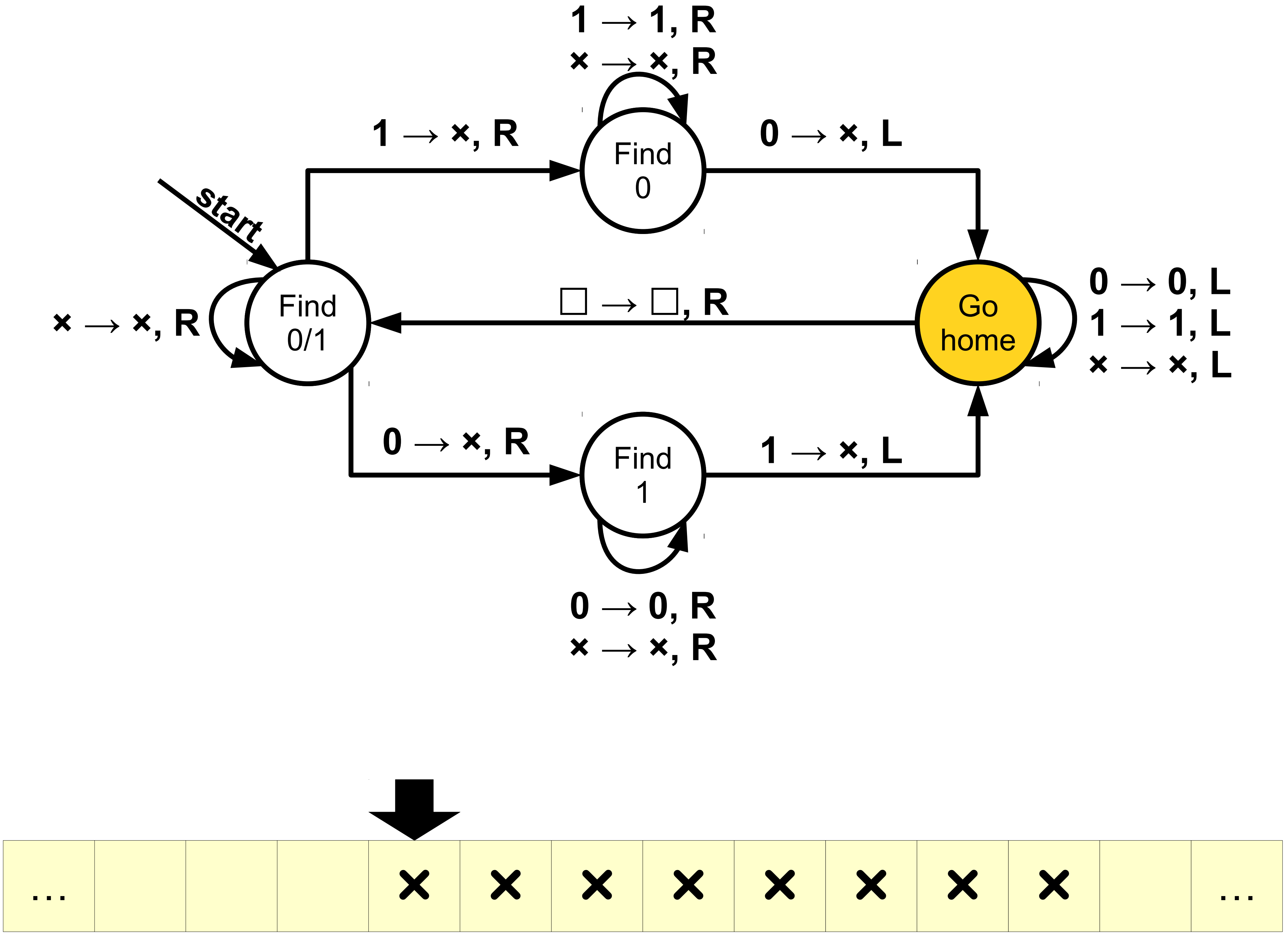

1 → 1, R
× → ×, R
1 → ×, R
Find 0
0 → ×, L
start
Find 0/1
× → ×, R
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R
…
×
×
×
×
×
×
×
×
…

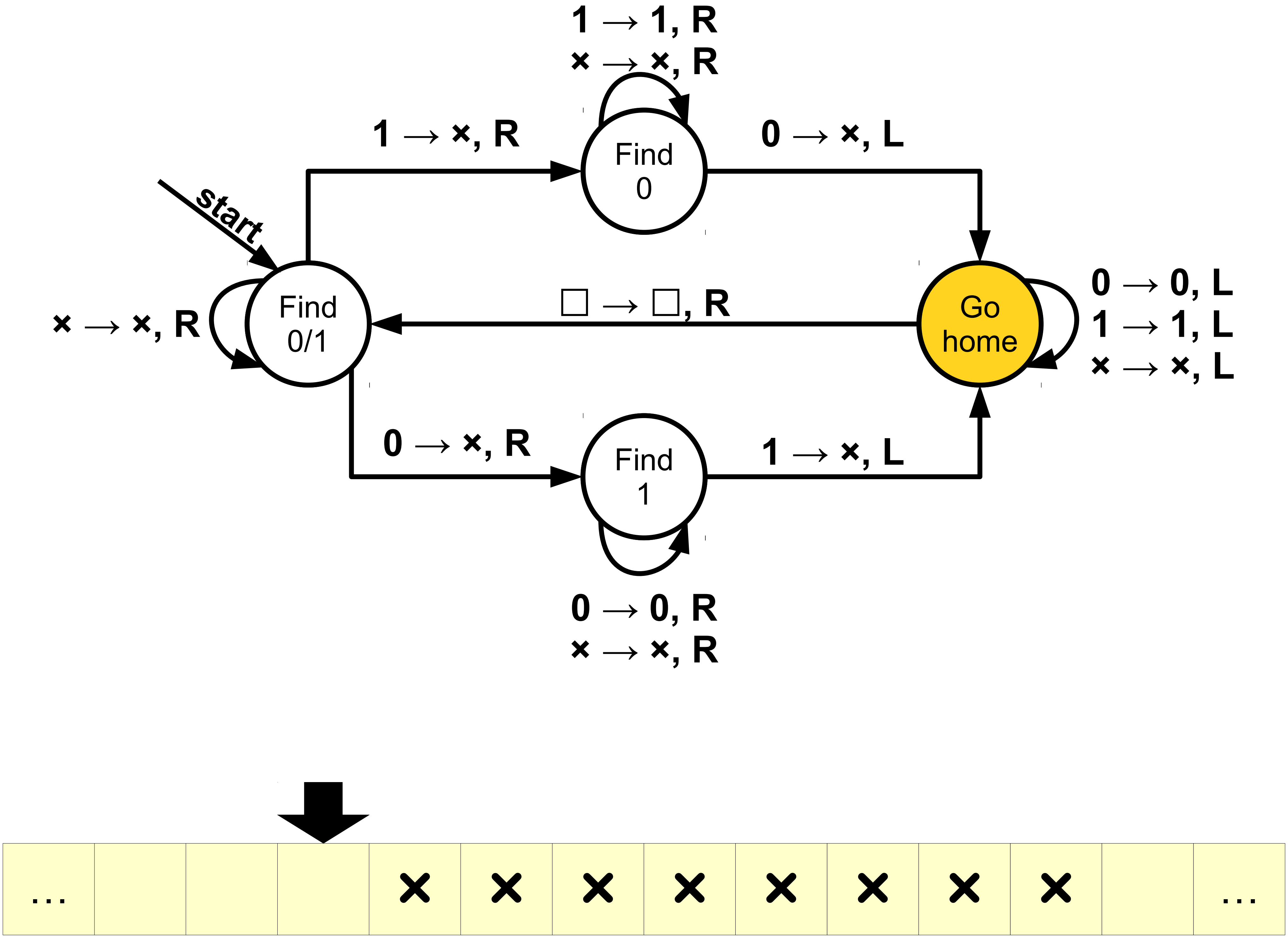

start
Find 0/1
× → ×, R
1 → ×, R
0 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
Find 1
0 → 0, R
× → ×, R
1 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
…
×
×
×
×
×
×
×
×
…

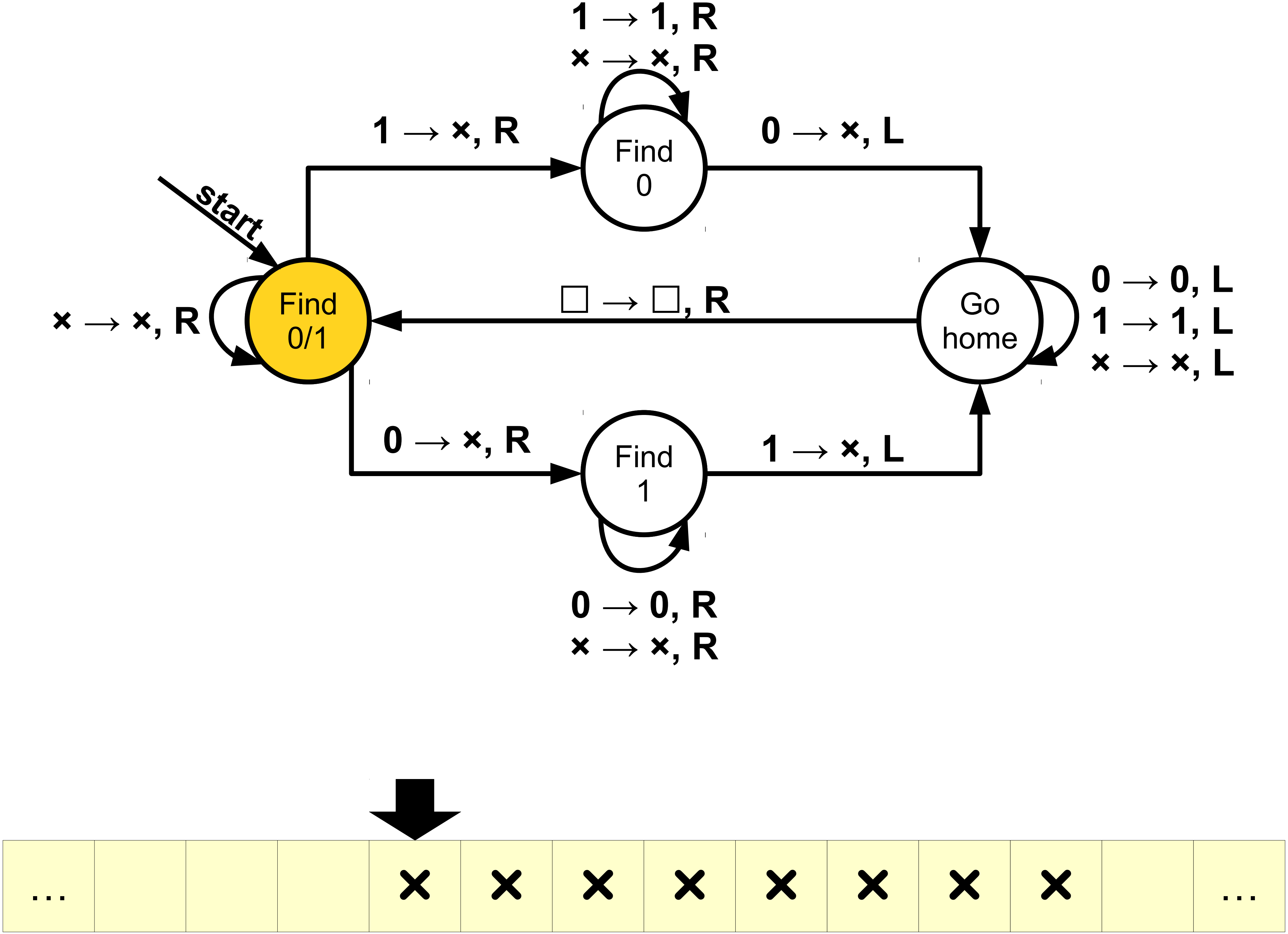

1 → 1, R
× → ×, R
1 → ×, R
Find 0
0 → ×, L
start
Find 0/1
× → ×, R
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R
…
×
×
×
×
×
×
×
×
…

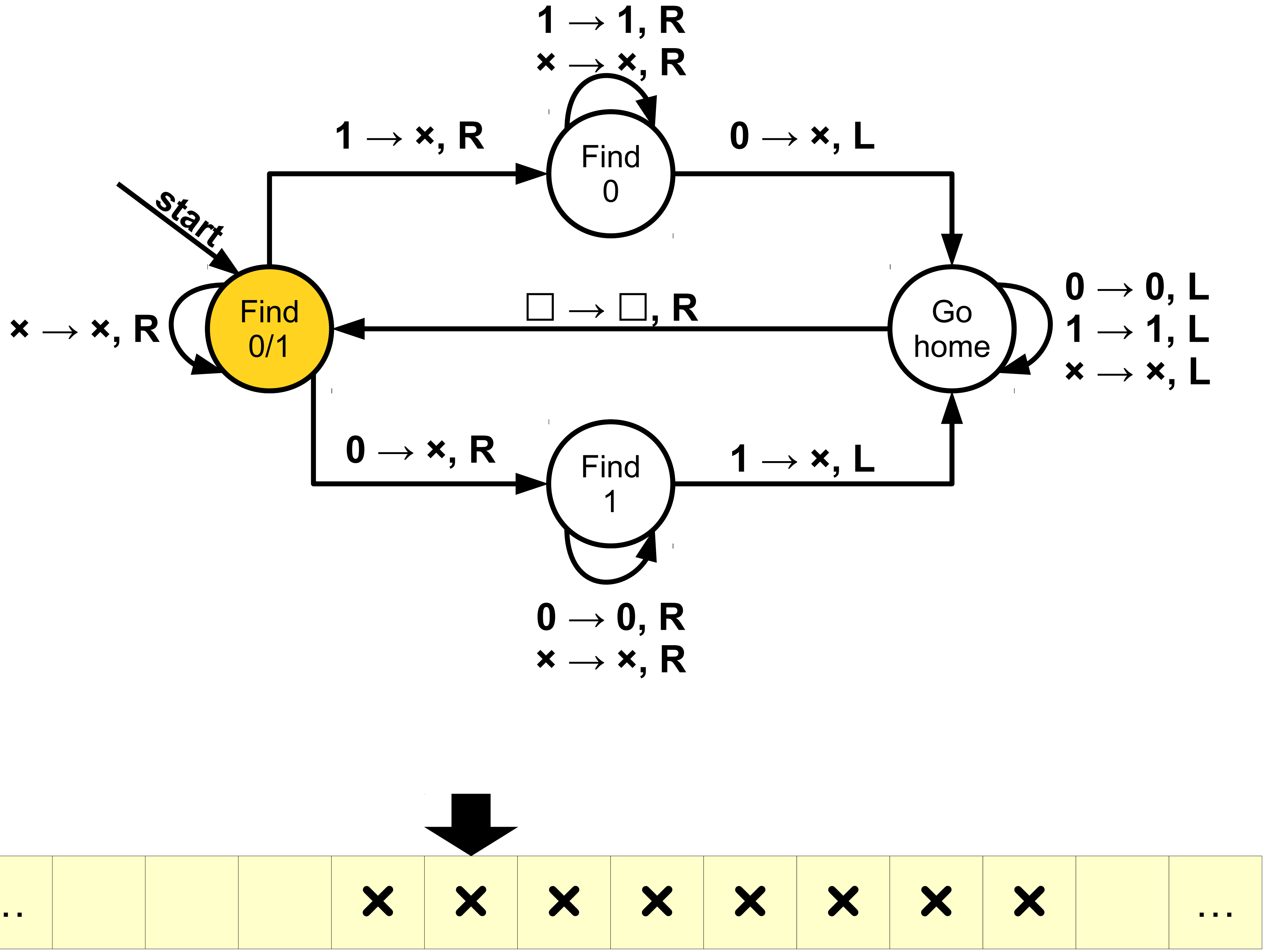

1 → 1, R
× → ×, R
1 → ×, R
0 → ×, L
start
Find 0
Find 0/1
× → ×, R
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R
…
×
×
×
×
×
×
×
×
…

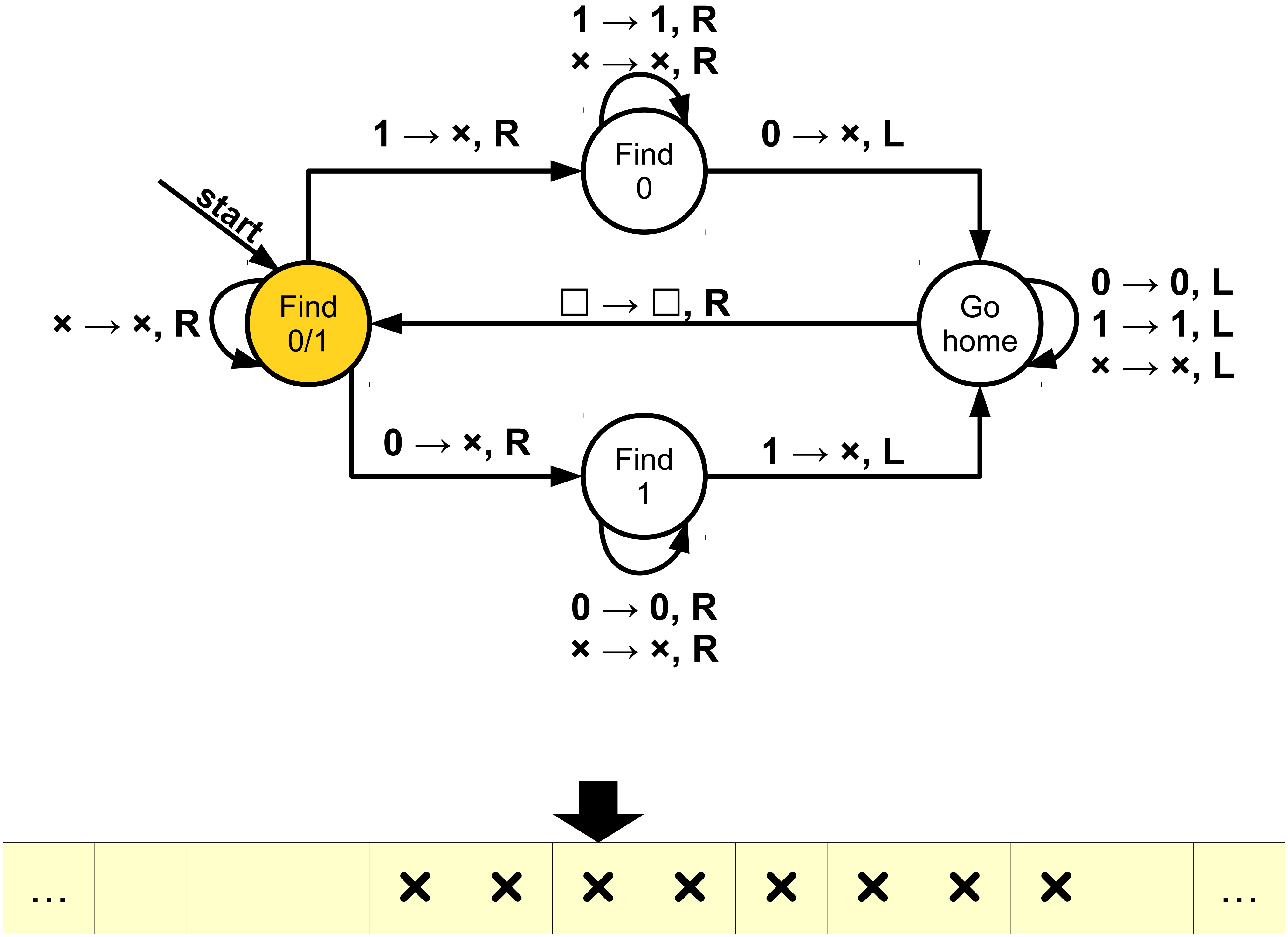

1 → 1, R
× → ×, R
1 → ×, R
0 → ×, L
start
Find 0
Find 0/1
× → ×, R
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R
…
×
×
×
×
×
×
×
×
…

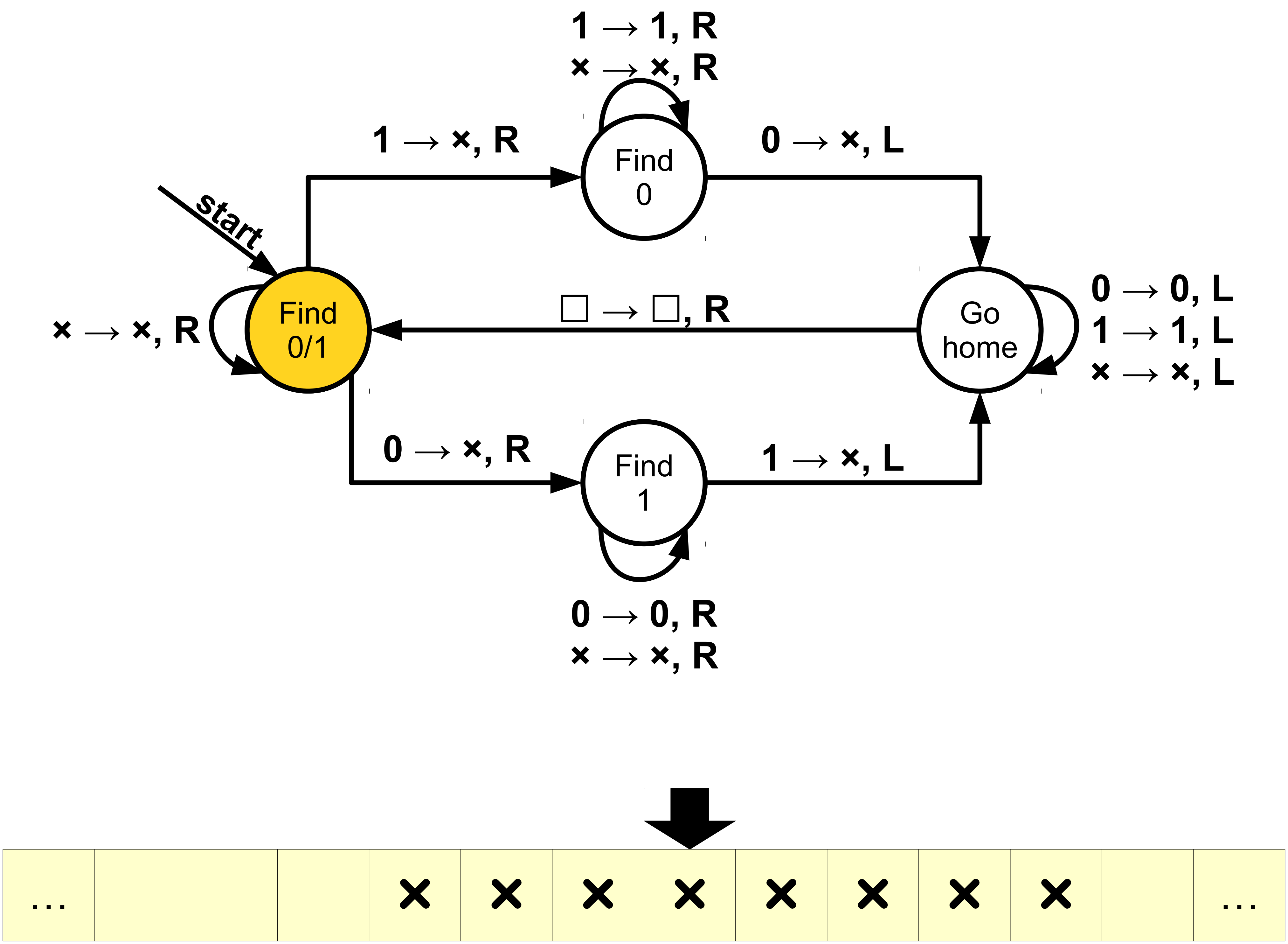

1 → 1, R
× → ×, R
1 → ×, R
Find 0
0 → ×, L
start
Find 0/1
× → ×, R
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R
…
×
×
×
×
×
×
×
×
…

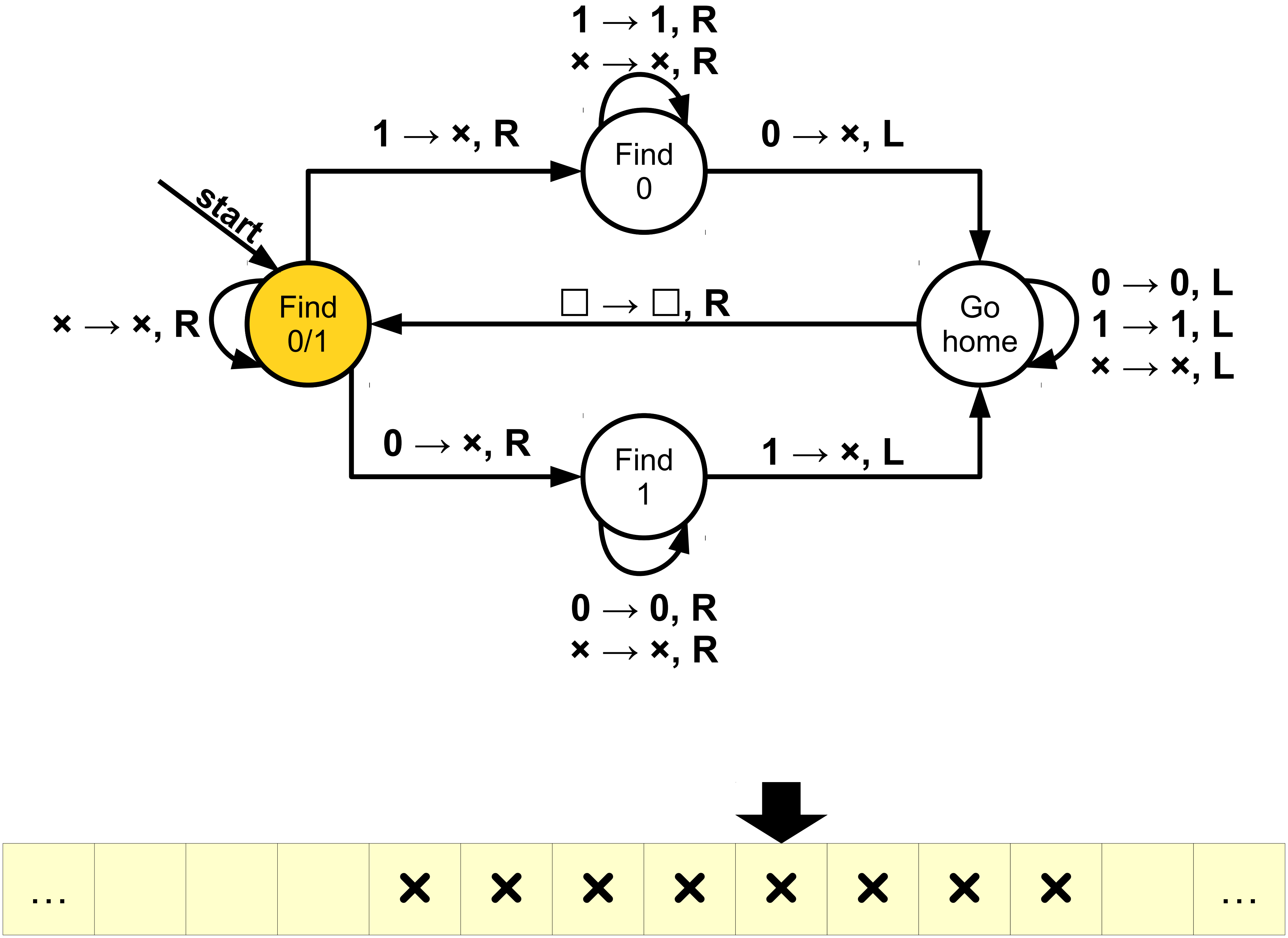

start
Find 0/1
× → ×, R
1 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
0 → 0, R
× → ×, R
1 → ×, L
…
×
×
×
×
×
×
×
×
…

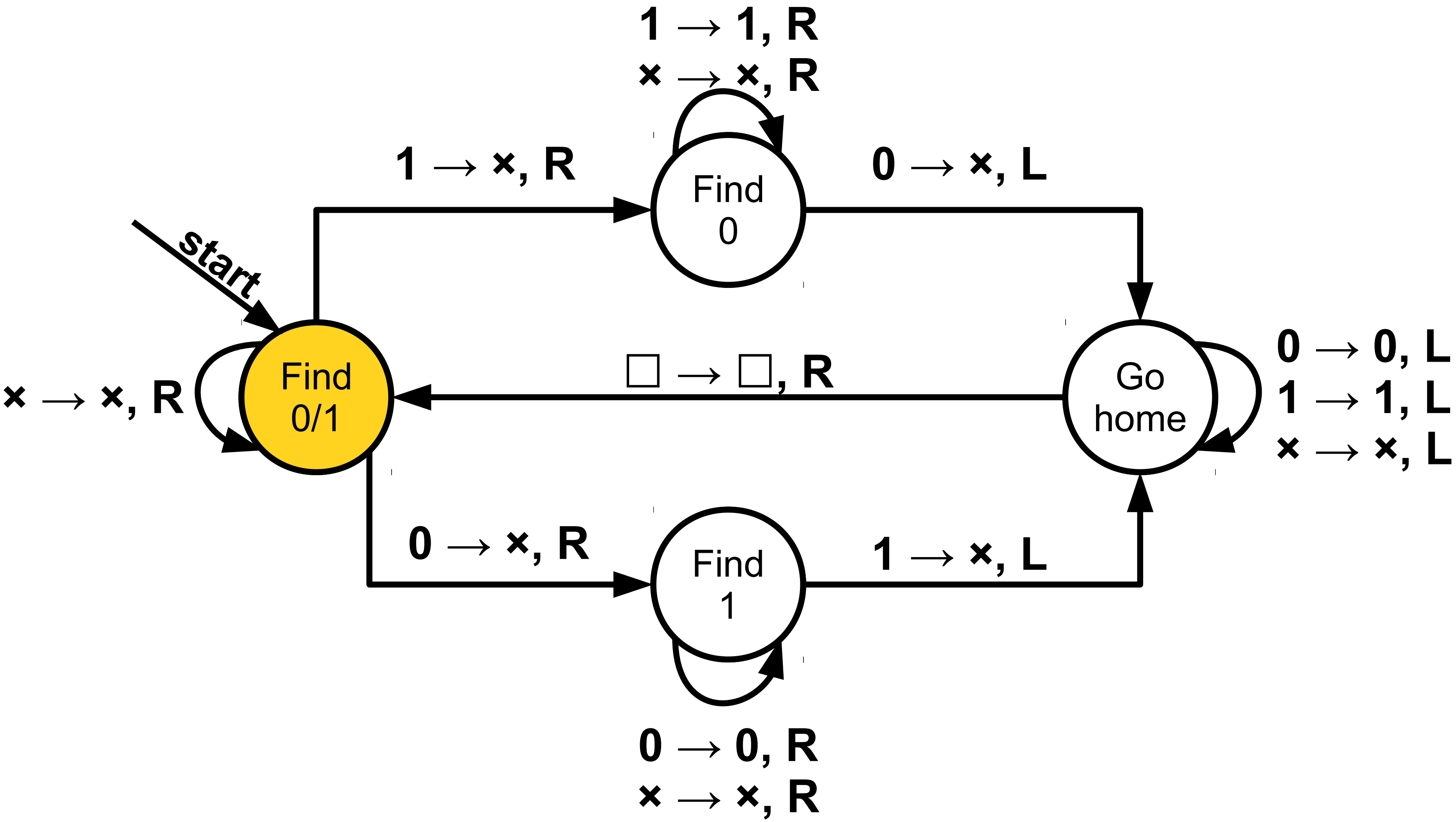

start
Find 0/1
× → ×, R
1 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
0 → ×, R
Find 1
0 → 0, R
× → ×, R
1 → ×, L
…
×
×
×
×
×
×
×
×
…

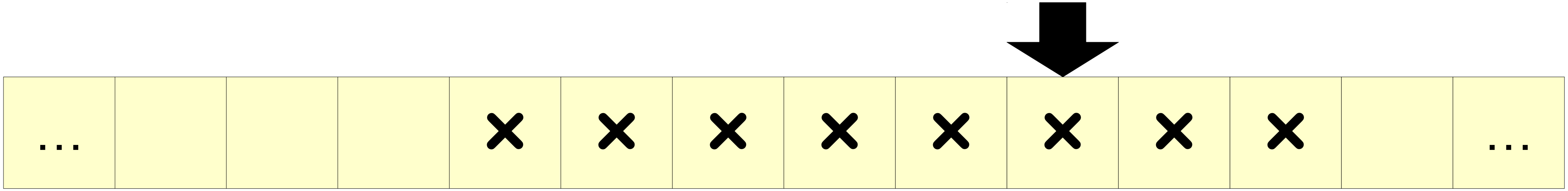

1 → 1, R
× → ×, R
1 → ×, R
Find
0
0 → ×, L
start
Find
0/1
× → ×, R
□ → □, R
Go
home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find
1
1 → ×, L
0 → 0, R
× → ×, R
…
×
×
×
×
×
×
×
×
…

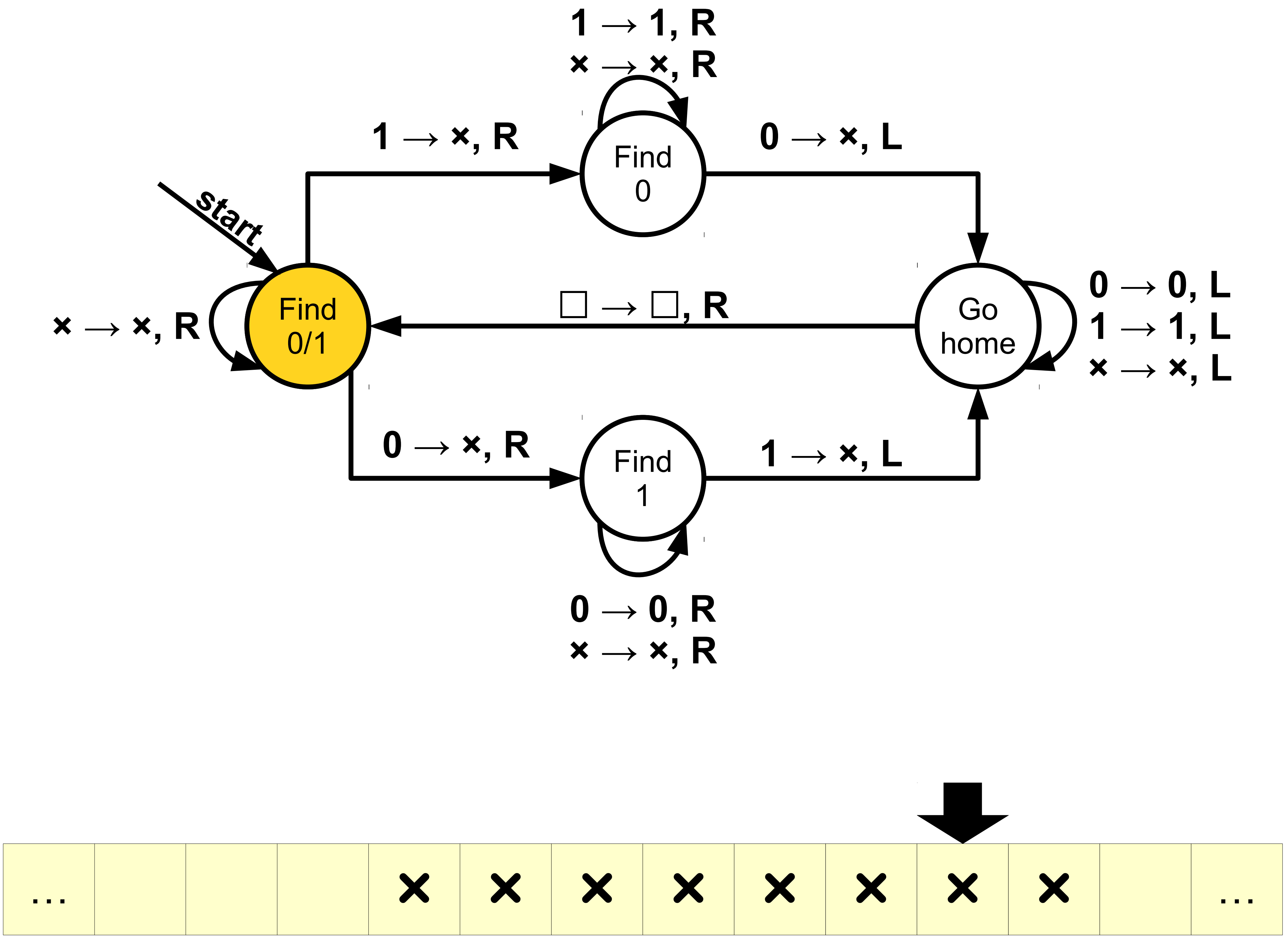

start
Find 0/1
× → ×, R
1 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
0 → ×, R
Find 1
0 → 0, R
× → ×, R
1 → ×, L
…
×
×
×
×
×
×
×
×
…

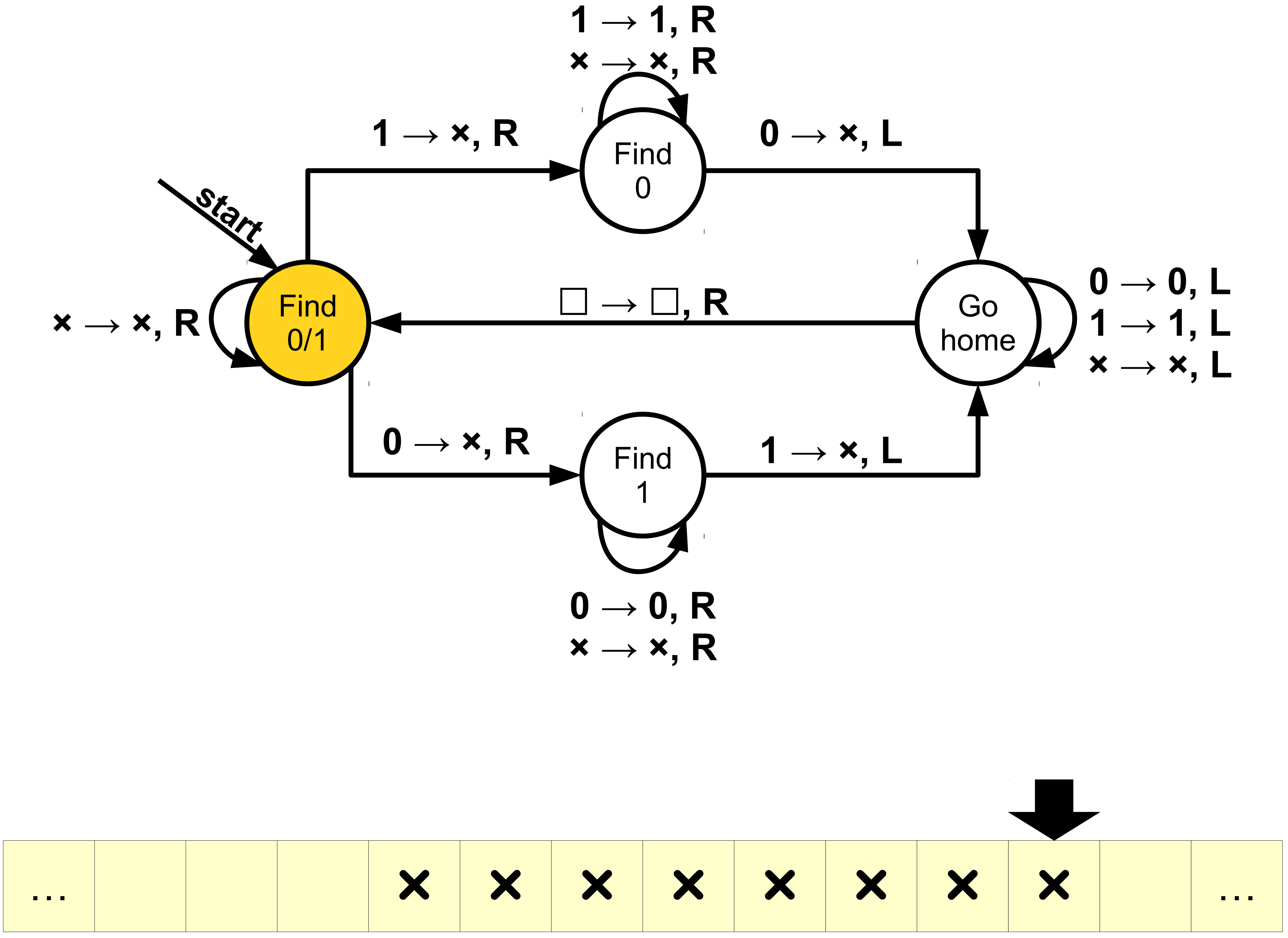

1 → 1, R
× → ×, R
1 → ×, R
0 → ×, L
start
Find 0
Find 0/1
× → ×, R
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R
…
×
×
×
×
×
×
×
×
…


start
Find 0/1
× → ×, R
1 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
0 → ×, R
Find 1
0 → 0, R
× → ×, R
1 → ×, L
…
×
×
×
×
×
×
×
×
…

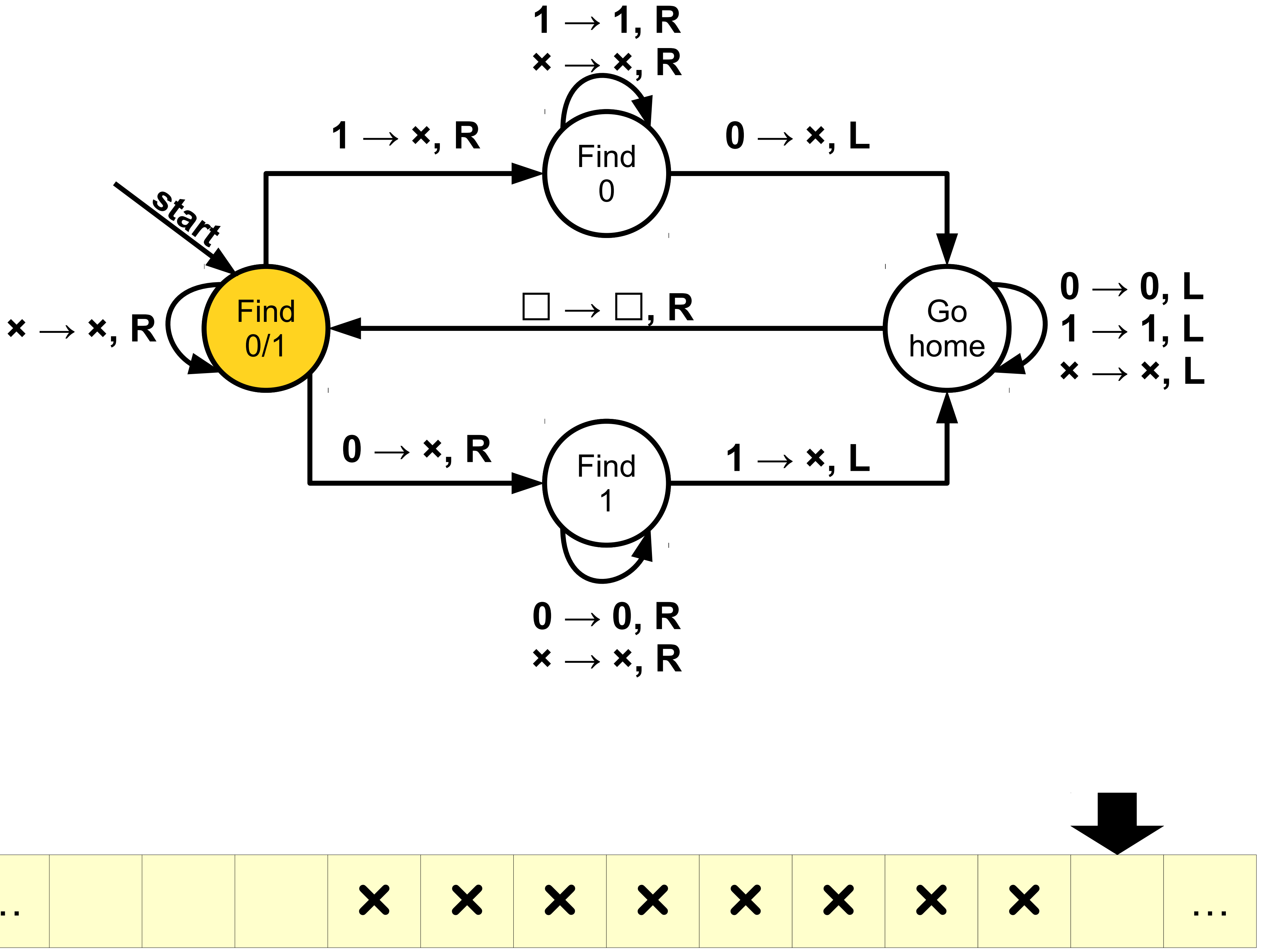

1 → 1, R
× → ×, R
1 → ×, R
0 → ×, L
start
Find 0/1
× → ×, R
Find 0
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
0 → 0, R
× → ×, R

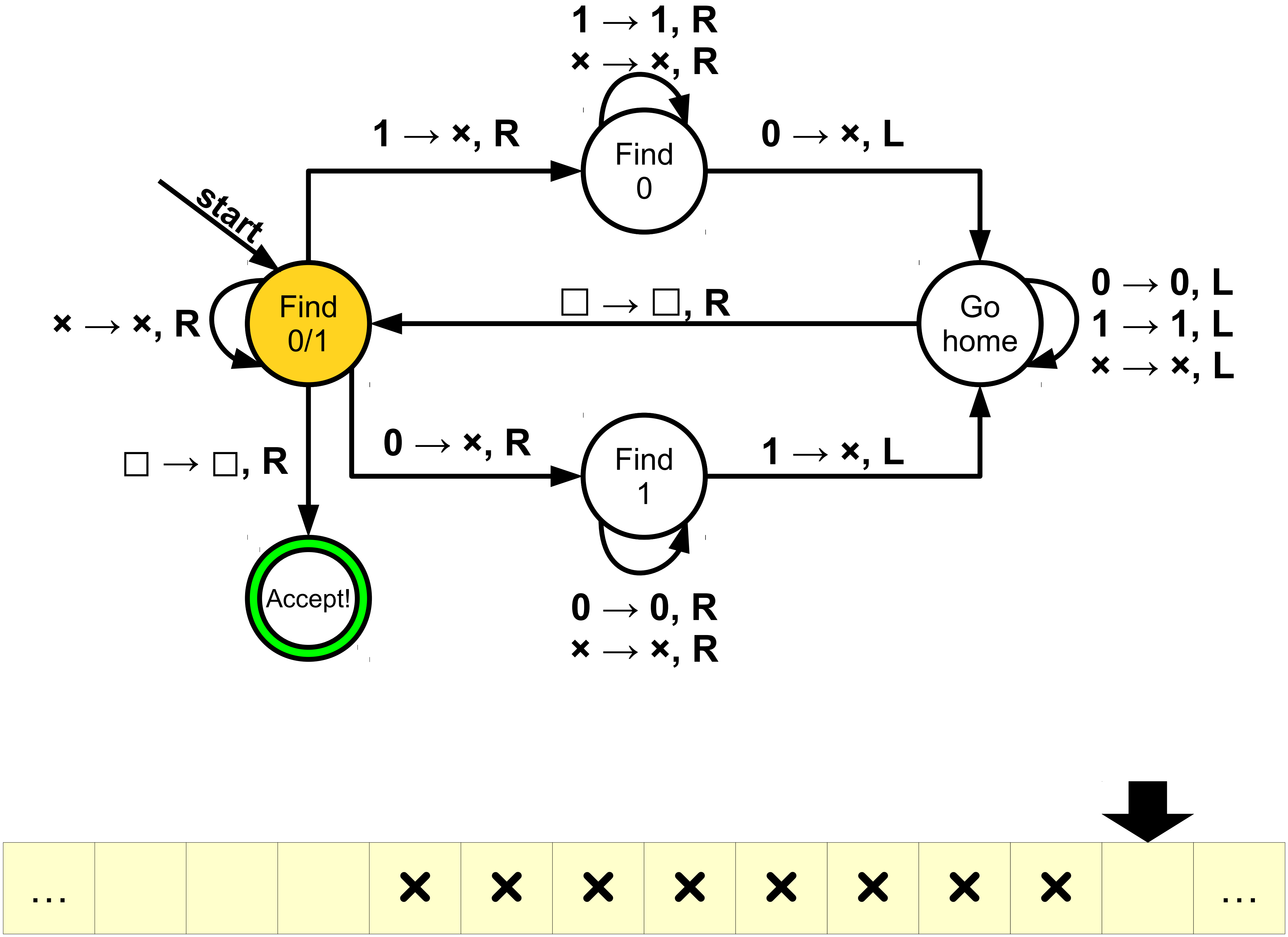

…
×
×
×
×
×
×
×
×
…

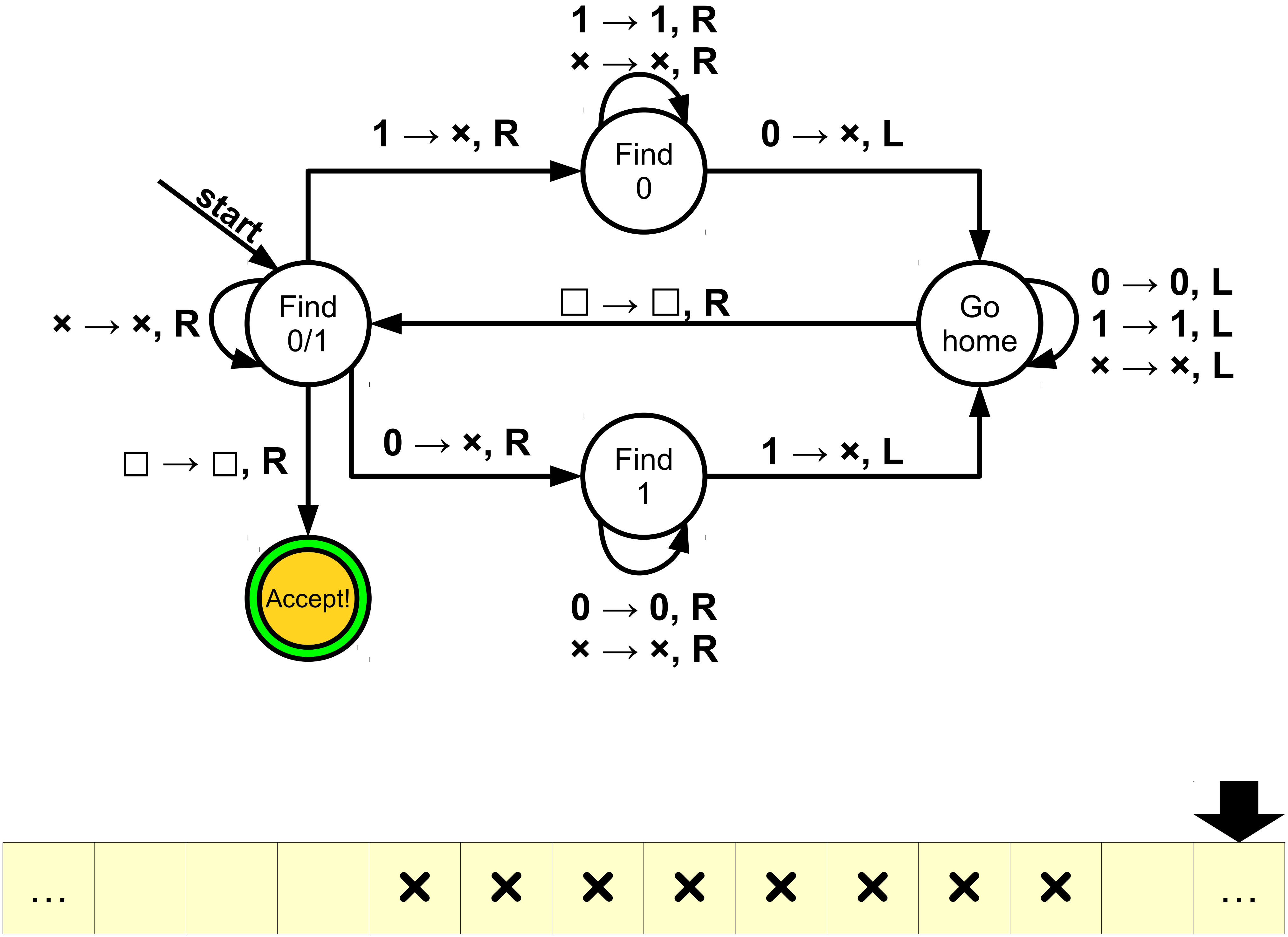

start
Find 0/1
× → ×, R
1 → ×, R
0 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
Find 1
0 → 0, R
× → ×, R
1 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
…
×
×
×
×
×
×
×
×
…

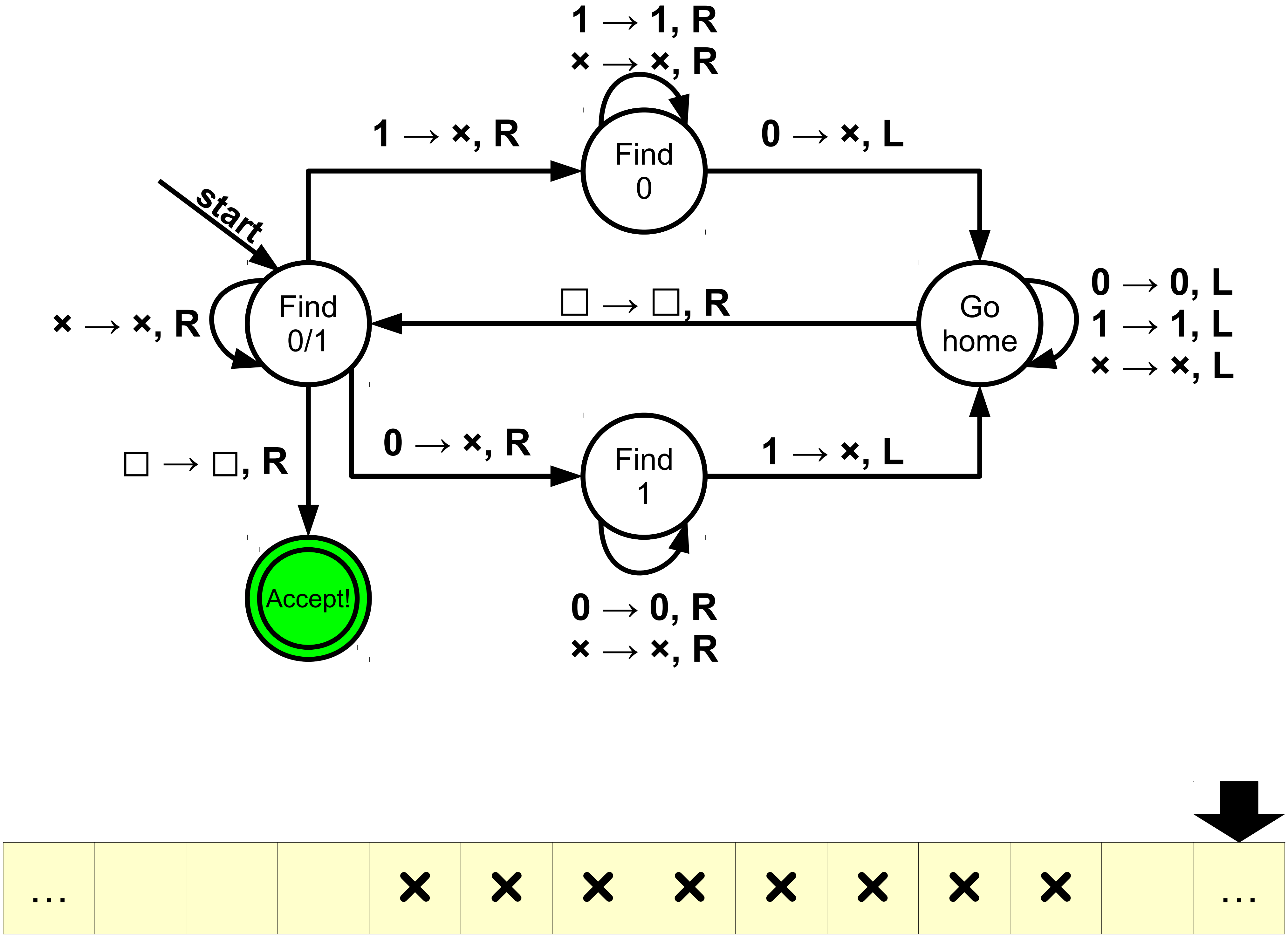


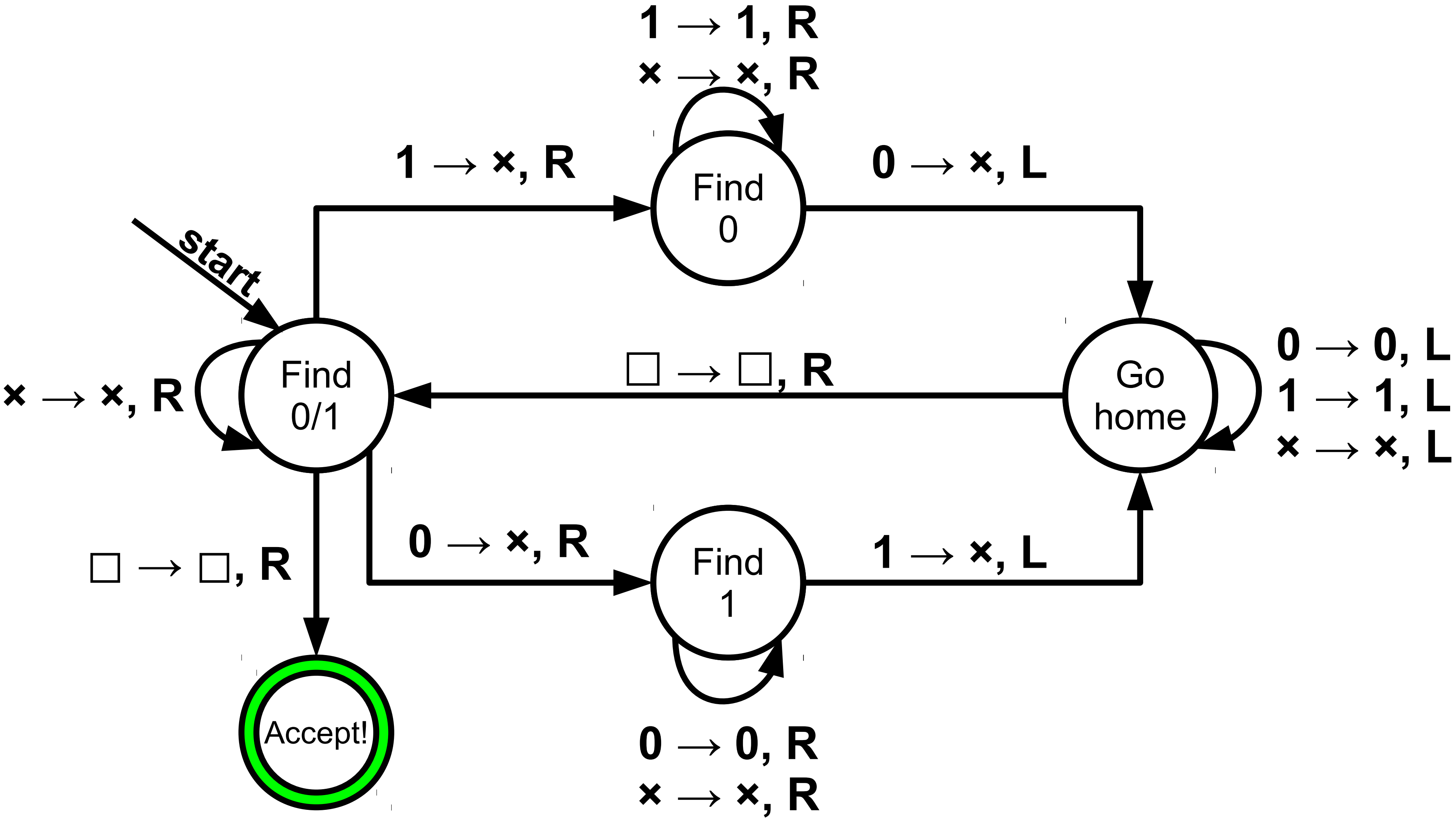
start
Find 0/1
× → ×, R
1 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
0 → ×, R
Find 1
0 → 0, R
× → ×, R
1 → ×, L
…
×
×
×
×
×
×
×
×
…

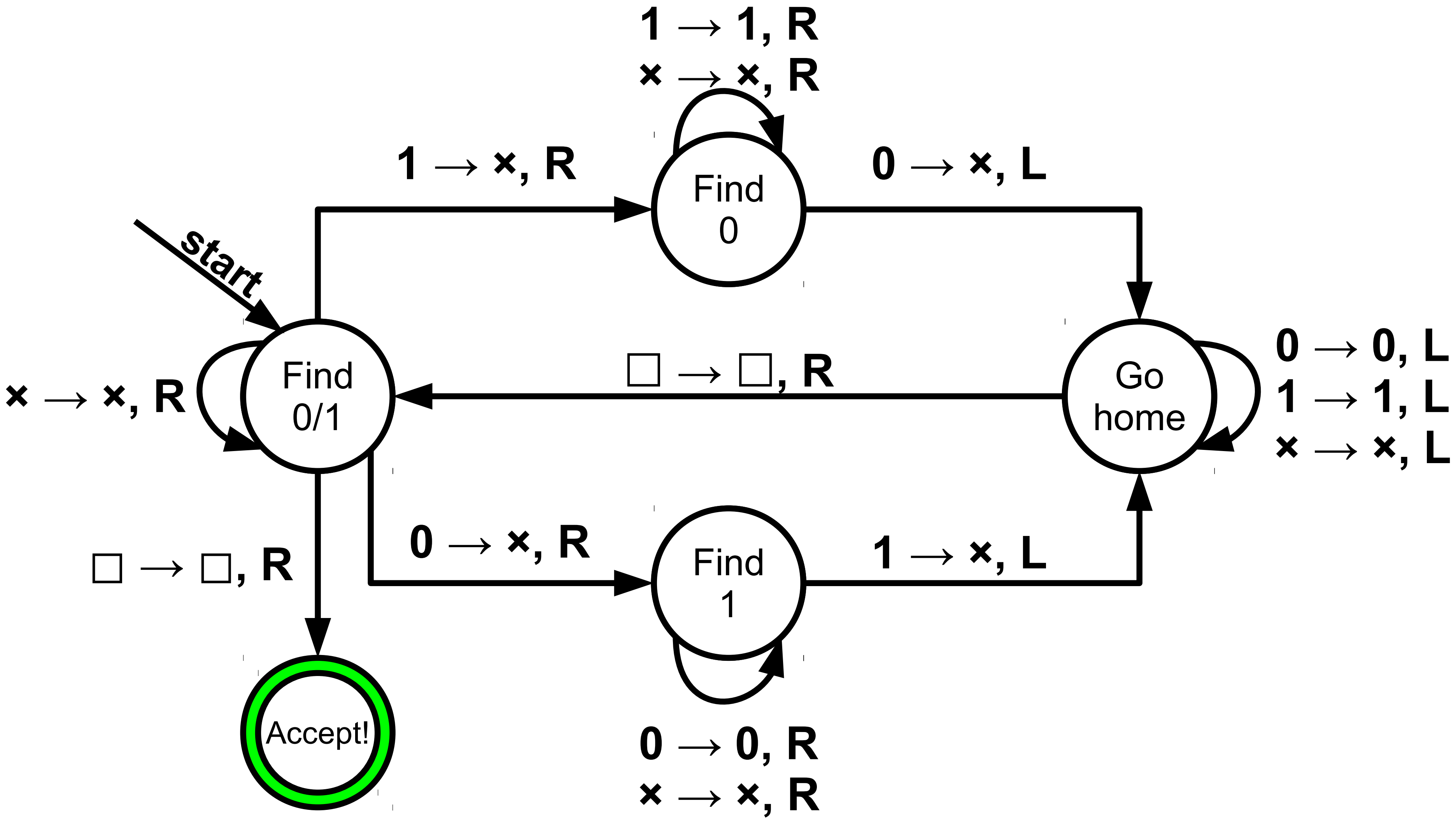

start
Find 0/1
× → ×, R
1 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
0 → ×, R
Find 1
0 → 0, R
× → ×, R
1 → ×, L
…
× × × × × × × ×
…


1 → 1, R
× → ×, R
1 → ×, R
0 → ×, L
start
Find 0
× → ×, R
Find 0/1
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
0 → ×, R
Find 1
1 → ×, L
Accept!
0 → 0, R
× → ×, R
…
×
×
×
×
×
×
×
×
…

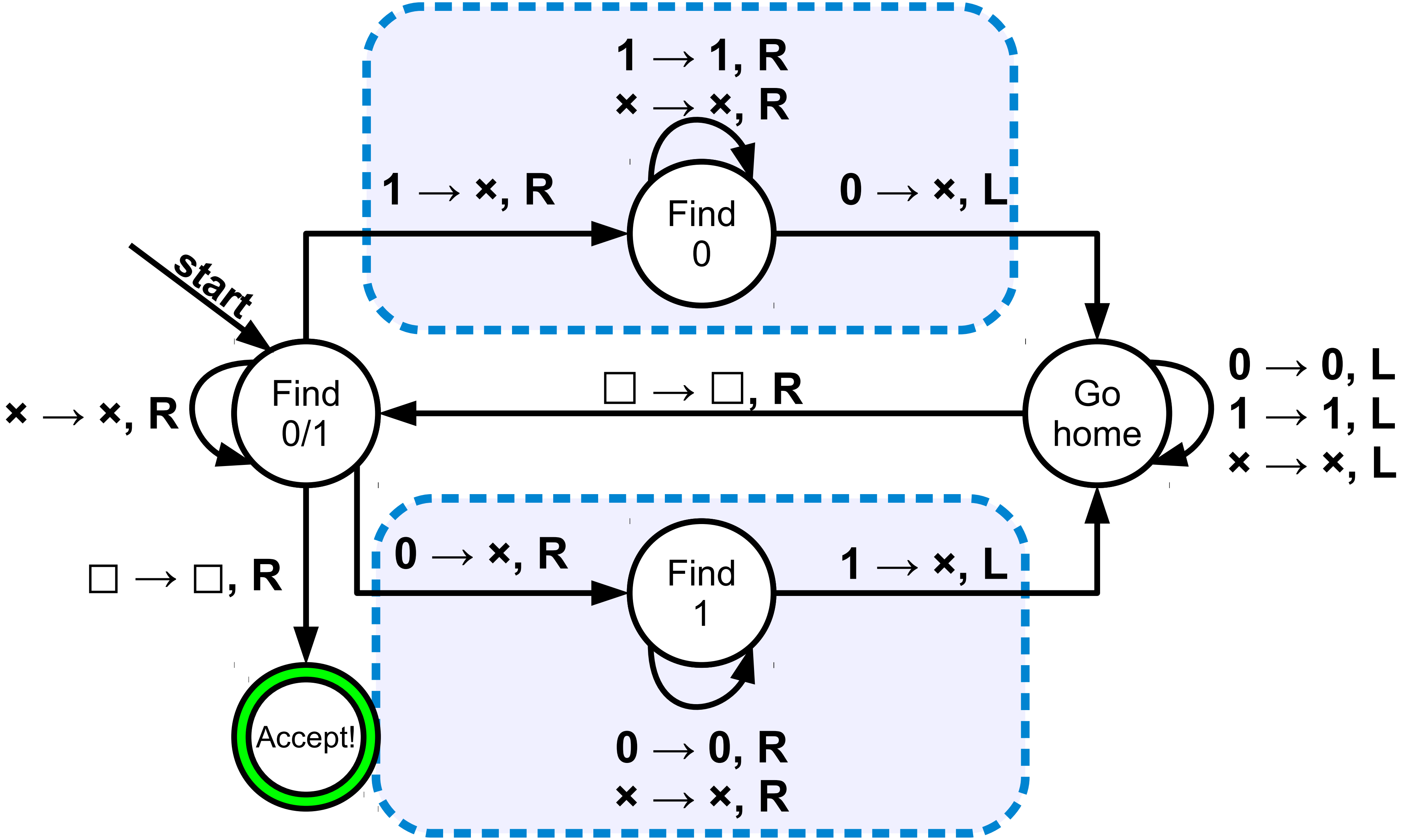

start
Find 0/1
× → ×, R
1 → ×, R
Find 0
1 → 1, R
× → ×, R
0 → ×, L
Go home
0 → 0, L
1 → 1, L
× → ×, L
□ → □, R
0 → ×, R
Find 1
0 → 0, R
× → ×, R
1 → ×, L
□ → □, R
Accept!
…
×
×
×
×
×
×
×
×
…


1 → 1, R
× → ×, R
1 → ×, R
0 → ×, L
start
Find 0
Find 0/1
× → ×, R
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
□ → □, R
Accept!
0 → 0, R
× → ×, R
…
×
×
×
×
×
×
×
×
…


1 → 1, R
× → ×, R
1 → ×, R
Find 0
0 → ×, L
start
Find 0/1
× → ×, R
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
□ → □, R
Accept!
0 → 0, R
× → ×, R



Going forward, we'll ignore the missing transitions and pretend they implicitly reject.


1 → 1, R
× → ×, R
1 → ×, R
Find 0
0 → ×, L
start
× → ×, R
Find 0/1
□ → □, R
Go home
0 → 0, L
1 → 1, L
× → ×, L
0 → ×, R
Find 1
1 → ×, L
□ → □, R
Accept!
0 → 0, R
× → ×, R

Constant Storage

- Sometimes, a TM needs to remember some additional information that can't be put on the tape.
- In this case, you can use similar techniques from DFAs and introduce extra states into the TM's finite-state control.
- The finite-state control can only remember one of finitely many things, but that might be all that you need!

Time-Out for Announcements!

Problem Set Seven

- Problem Set Seven is due on Friday.
- Have questions? Please feel free to stop by office hours or to ask questions on Piazza.

Second Midterm Exam

- The second midterm exam is next **Monday, February 29** from 7PM – 10PM, location TBA.
- Topic coverage:
  - Focus is on PS4 – PS6 and lectures 09 – 16.
  - Topics from PS7 and from lecture 17 onward will not be tested… yet. ☺
  - ***Major topics:*** strict orders, graphs, the pigeonhole principle, induction, finite automata, regular expressions, regular languages, closure properties.
- Policies and procedures same as the first midterm:
  - Three hours, four questions.
  - Closed-computer, closed-book, and limited-note. You can have a double-sided 8.5” × 11” sheet of paper with you when you take the exam.

Preparing for the Exam

- We have just released four sets of extra practice problems (EPP4 – EPP7) online. Solutions will go out on Wednesday.
- We will be holding a practice midterm on **Wednesday** from **7PM – 10PM** in **Bishop Auditorium**.
- By popular demand, we've put together *two* practice exams – one that we'll give out at the practice exam and one that will be posted online on Wednesday.
- We've also released a set of challenge problems, and this week's CS103A class will be a cumulative review.
- That's (by my reckoning) four sets of practice problems, two practice exams, one set of challenge problems, and one set of CS103A problems. If that's not enough, let me know and I'll see what I can do.

Stanford Women
In Computer Science

CASUAL CS DINNER

{w}

Wednesday Feb. 24 from 5:30-7:30pm at the WCC
RSVP at goo.gl/forms/U2JY1e9CSu

Come have dinner with CS students and faculty.
Everyone is welcome, especially students
just starting out in CS!

Your Questions

“What's your favorite (and lesser-known) place on campus?”

There (used to be? still is?) a fire escape on one of the inner quad buildings that lets you climb up to the third floor. You get a great view and it's nice and quiet. It's a great place to study or cuddle and watch a movie.

“What keeps you motivated?”

I never cease to be amazed by the world. There's always so much to learn and discover.

Which reminds me – I haven't yet asked you the Three Key Questions yet!

Three Questions

- What is something that you now know that, at the start of the quarter, you knew you didn't know?
- What is something that you now know that, at the start of the quarter, you *didn't* know you didn't know?
- What is something that you *don't* know that, at the start of the quarter, you didn't know you didn't know?

Back to CS103!

Another TM Design

- Consider the following language over $\Sigma = \{\texttt{0}, \texttt{1}\}$:

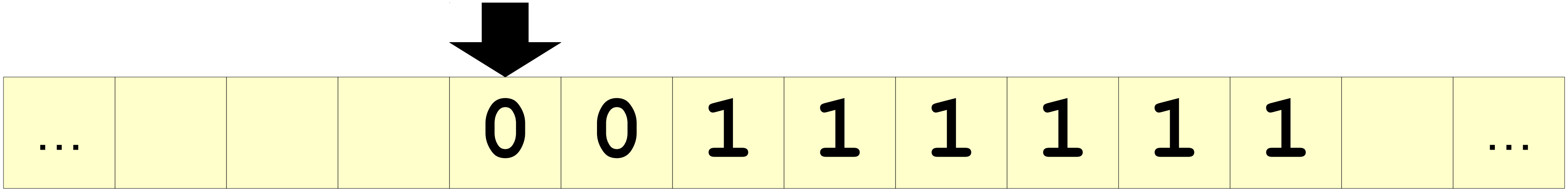
$$L = \{ \texttt{0}^n \texttt{1}^m \mid n, m \in \mathbb{N} \text{ and } m \text{ is a multiple of } n \}$$

- Is this language regular?
- How might we design a TM for this language?

An Observation

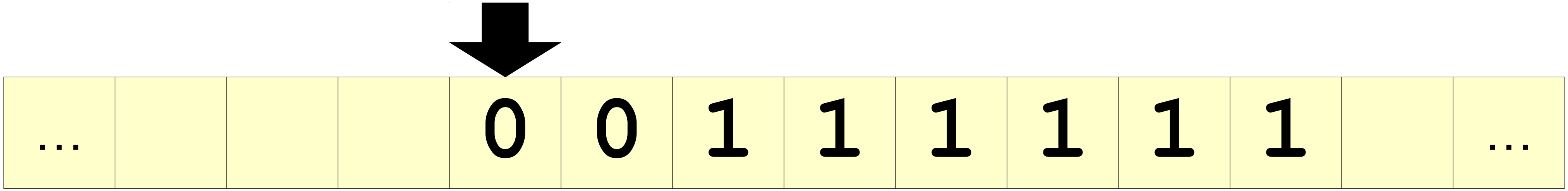
- We can recursively describe when one number m is a multiple of n:
  - If $m = 0$, then m is a multiple of n.
  - Otherwise, m is a multiple of n iff $m - n$ is a multiple of n.
- **Idea:** Repeatedly subtract n from m until m becomes zero (good!) or drops below zero (bad!)

The Challenge

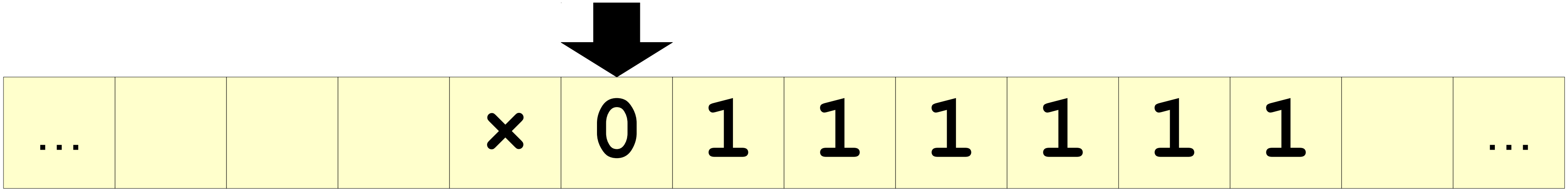


…				0	0	1	1	1	1	1	1		…

One Solution

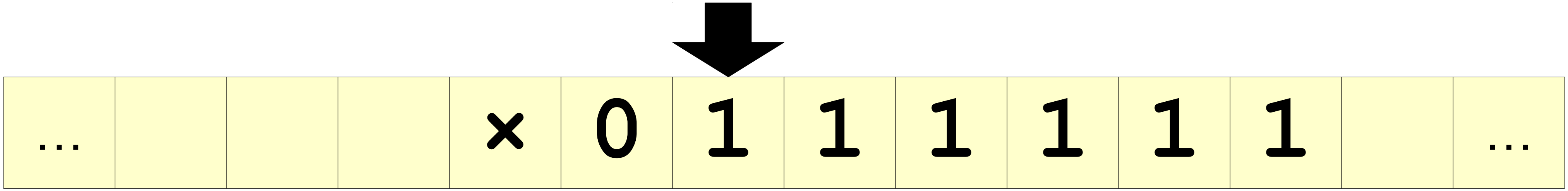


One Solution



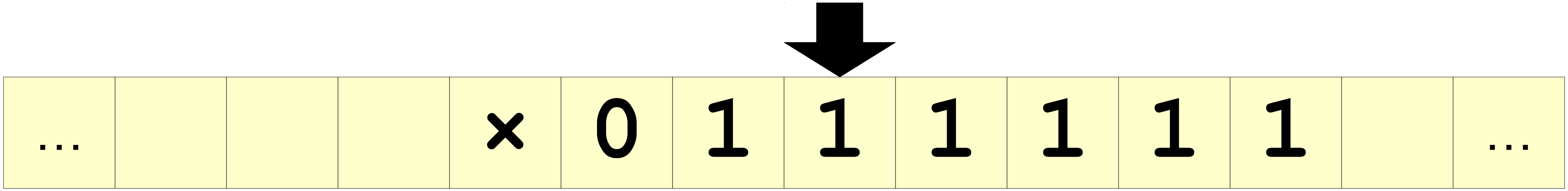
…				×	0	1	1	1	1	1	1		…

One Solution



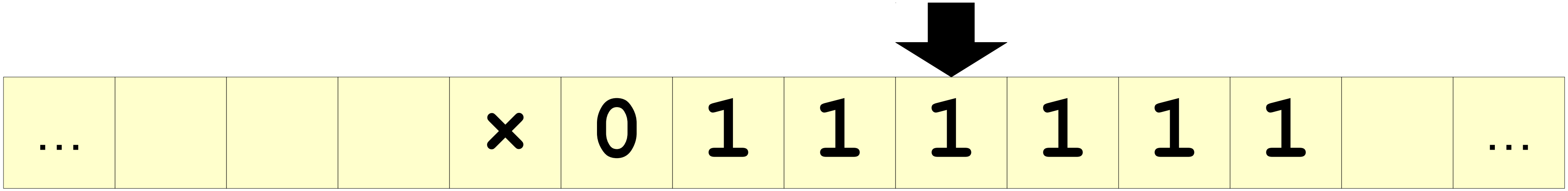
…				×	0	1	1	1	1	1	1		…

One Solution



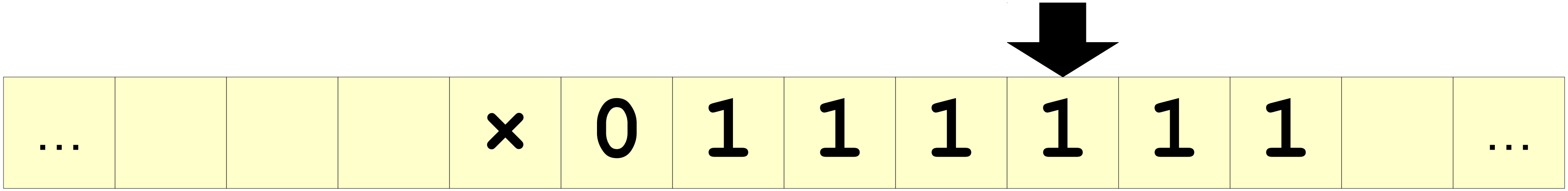
…				×	0	1	1	1	1	1	1		…

One Solution

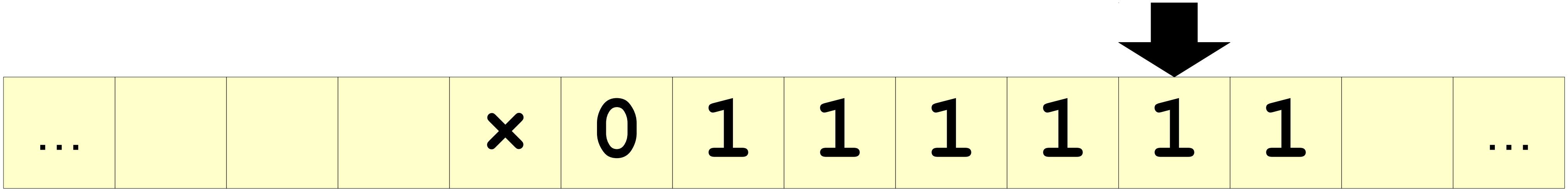


…				×	0	1	1	1	1	1	1		…

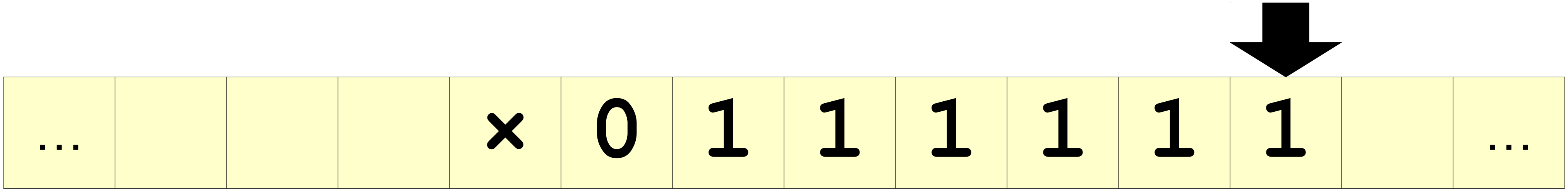
One Solution



One Solution

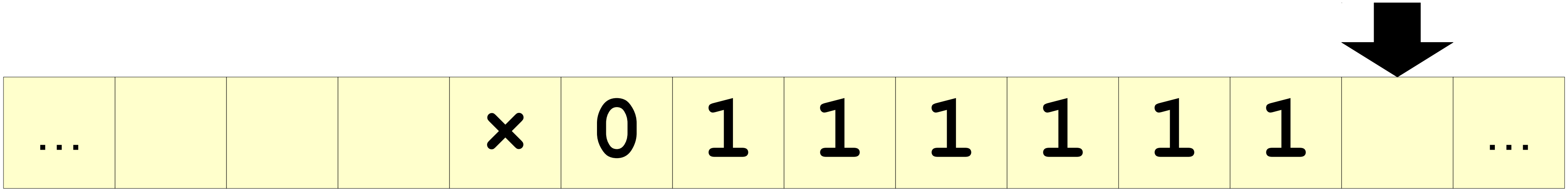


One Solution



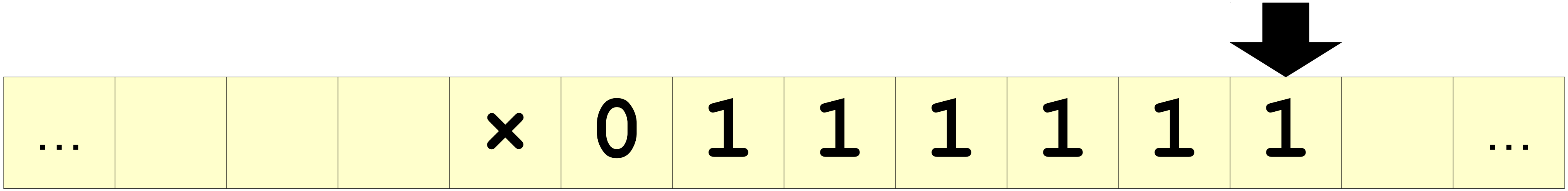
…				×	0	1	1	1	1	1	1		…

One Solution



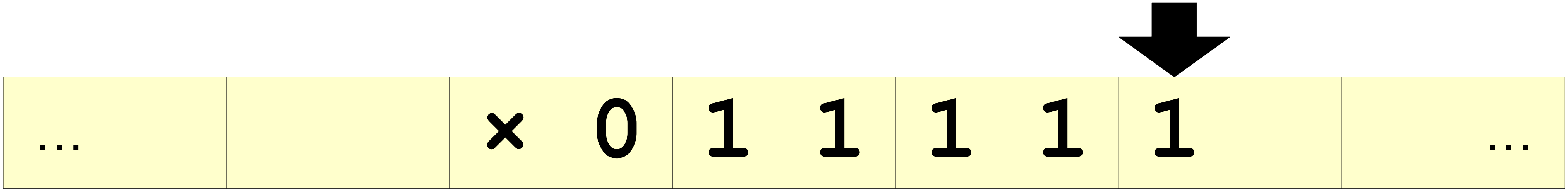
…				×	0	1	1	1	1	1	1		…

One Solution



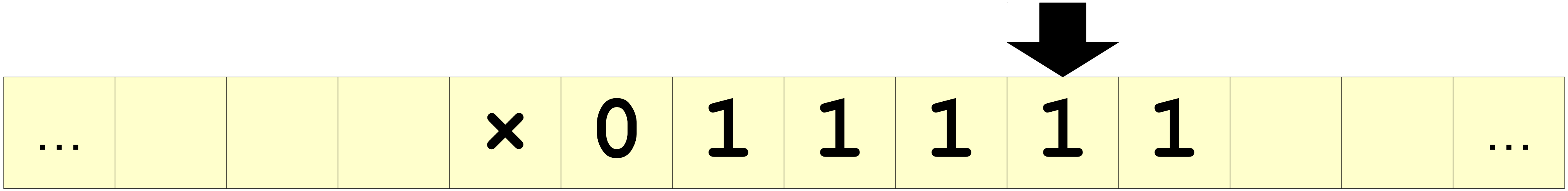
…				×	0	1	1	1	1	1	1		…

One Solution

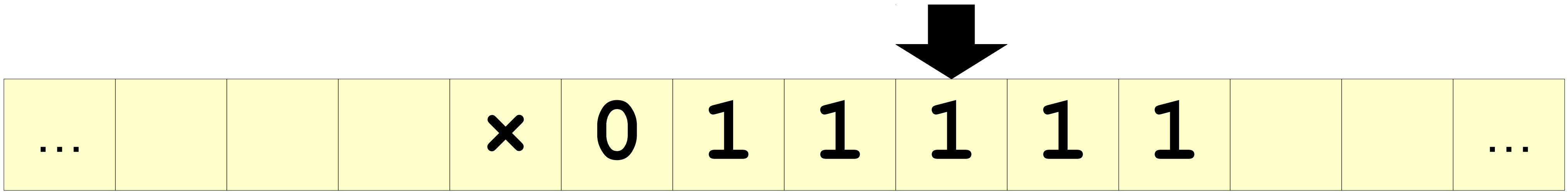


… × 0 1 1 1 1 1 …

One Solution

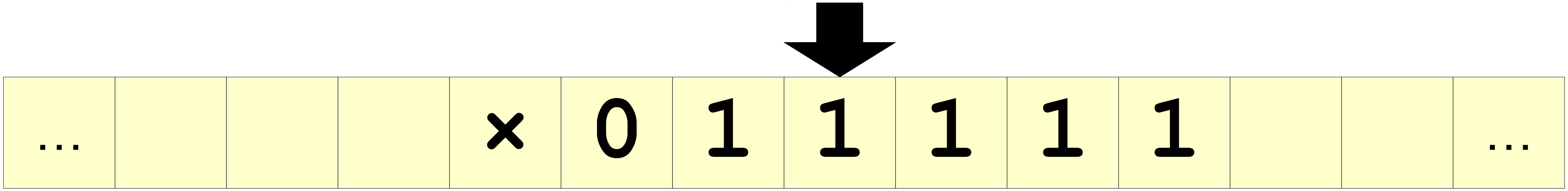


One Solution

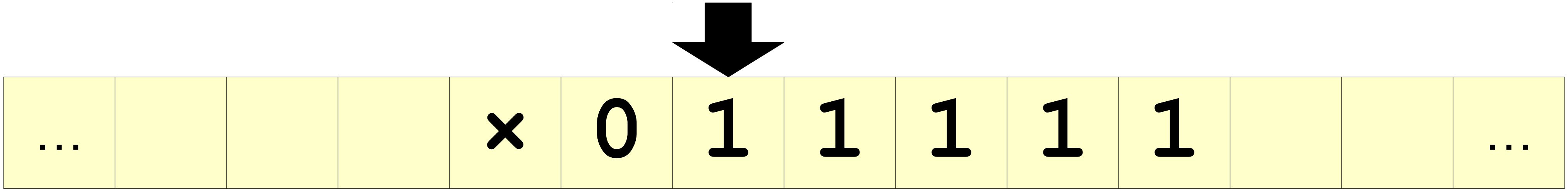


…				×	0	1	1	1	1	1			…

One Solution

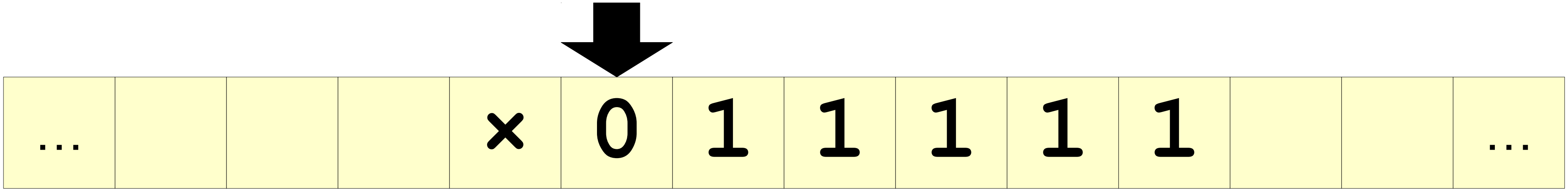


One Solution



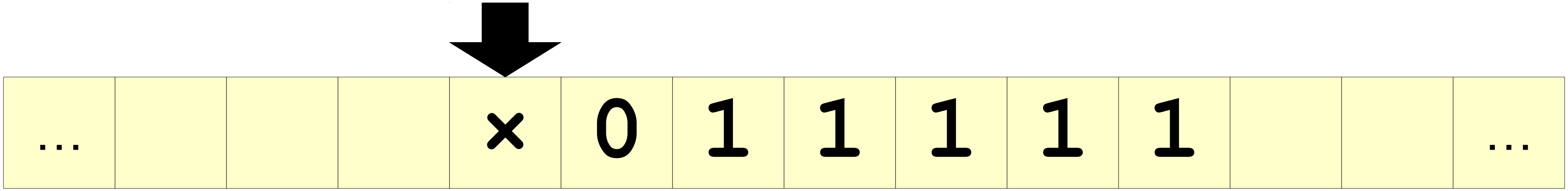
…				×	0	1	1	1	1	1			…

One Solution



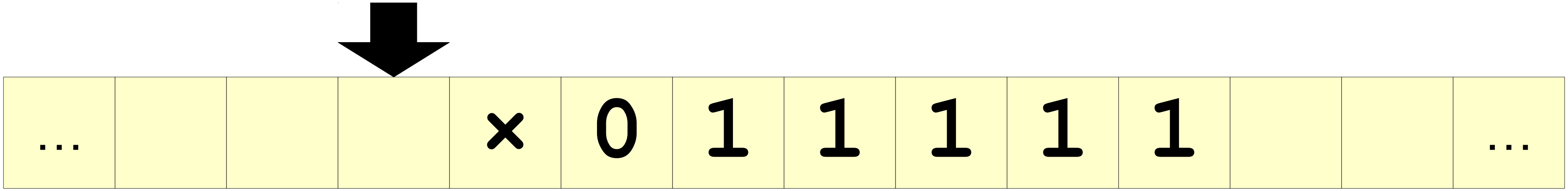
…				×	0	1	1	1	1	1			…

One Solution



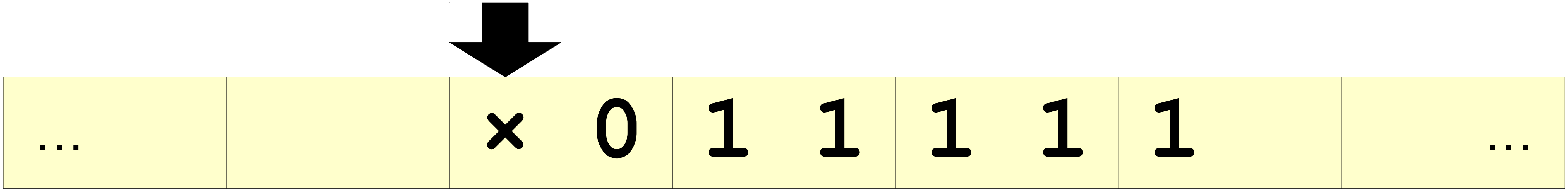
…				×	0	1	1	1	1	1			…

One Solution



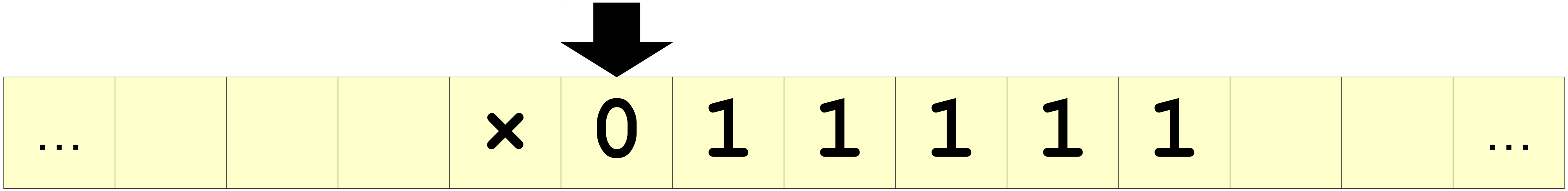
…				×	0	1	1	1	1	1			…

One Solution

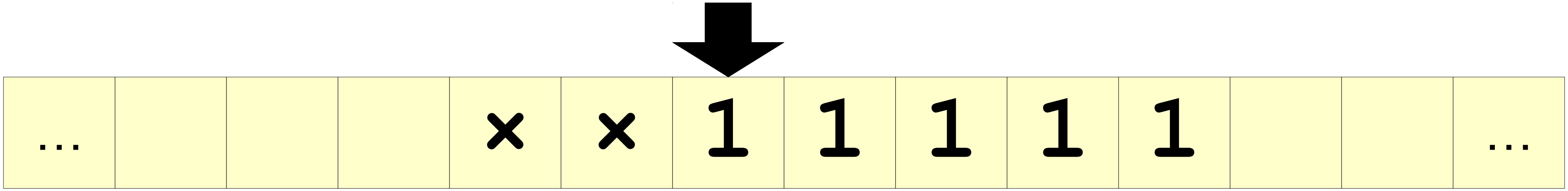


…				×	0	1	1	1	1	1			…

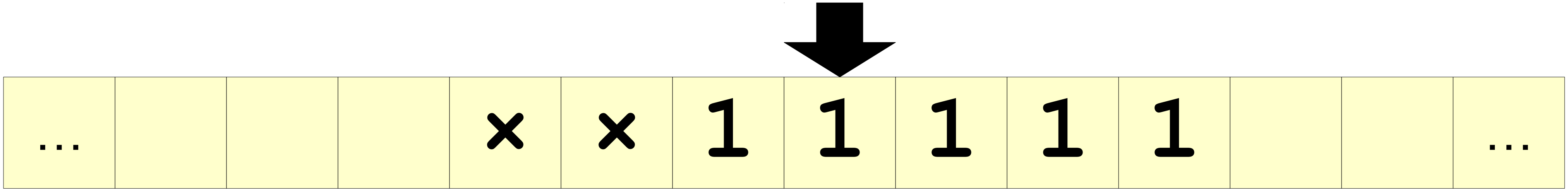
One Solution



One Solution

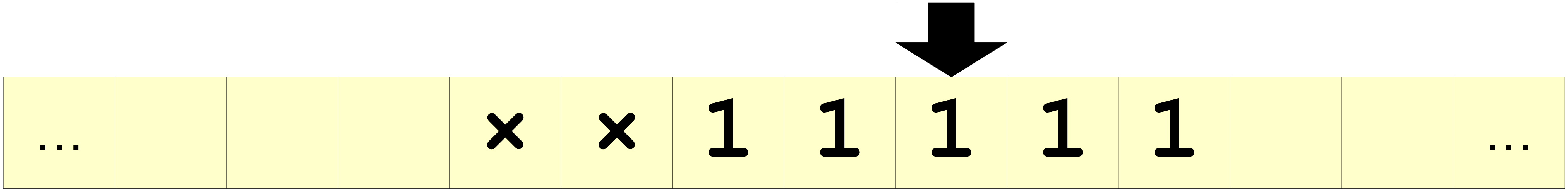


One Solution



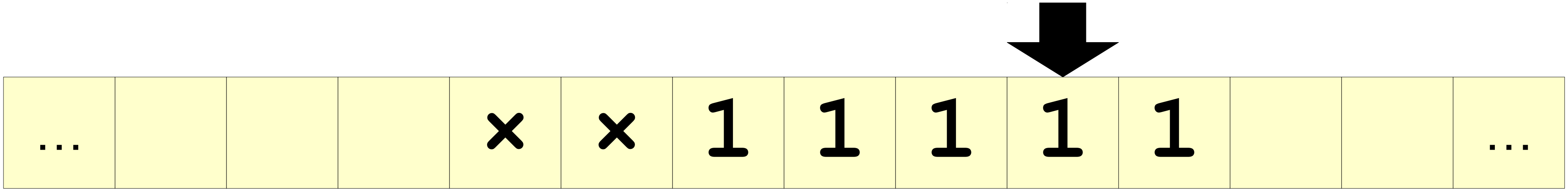
…				×	×	1	1	1	1	1			…

One Solution



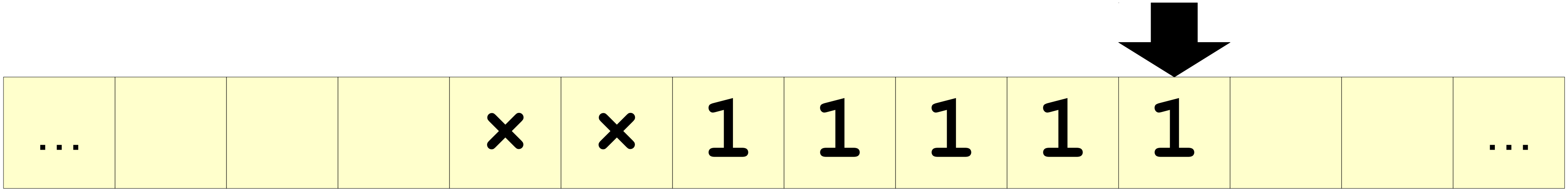
…				×	×	1	1	1	1	1			…

One Solution



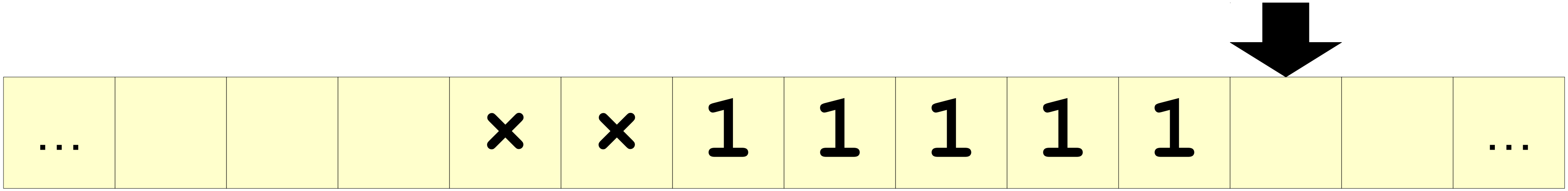
…				×	×	1	1	1	1	1			…

One Solution

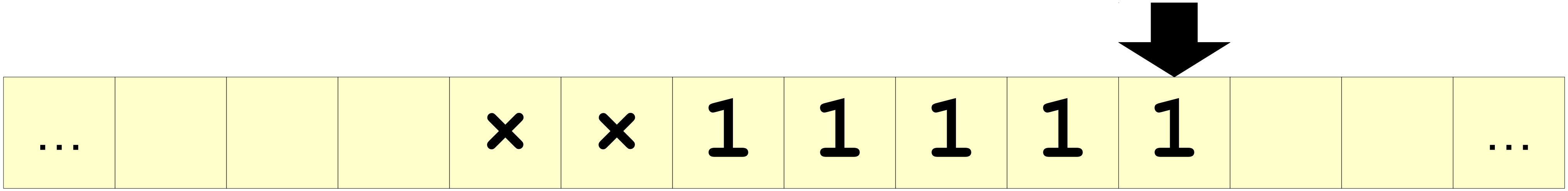


…				×	×	1	1	1	1	1			…

One Solution

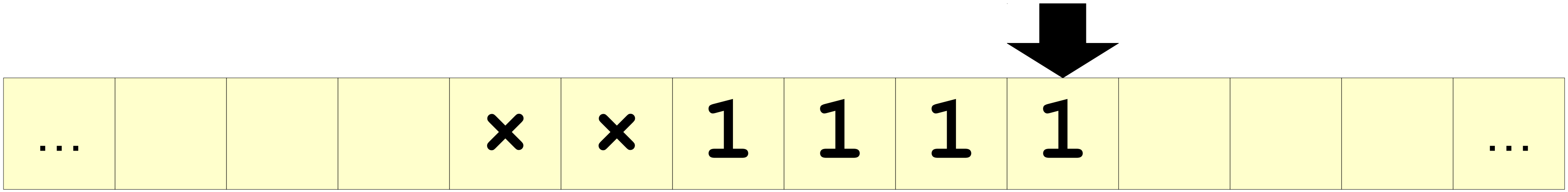


One Solution



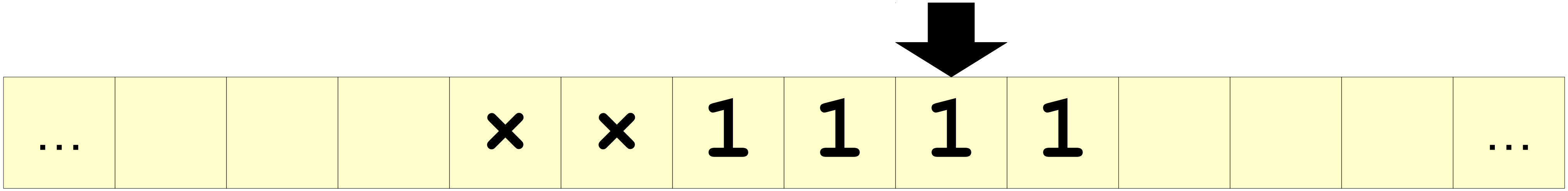
… × × 1 1 1 1 1 …

One Solution

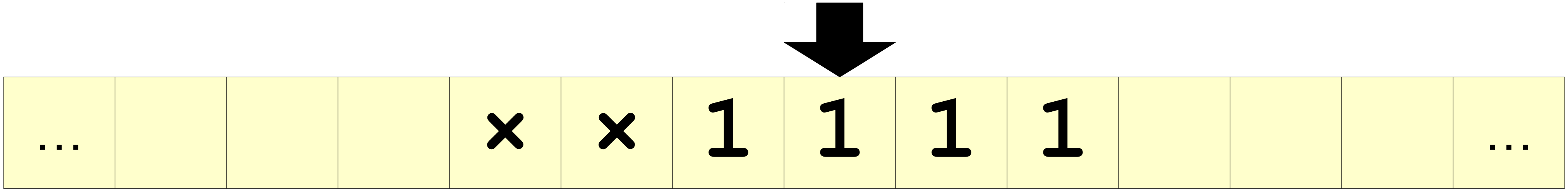


…				×	×	1	1	1	1				…

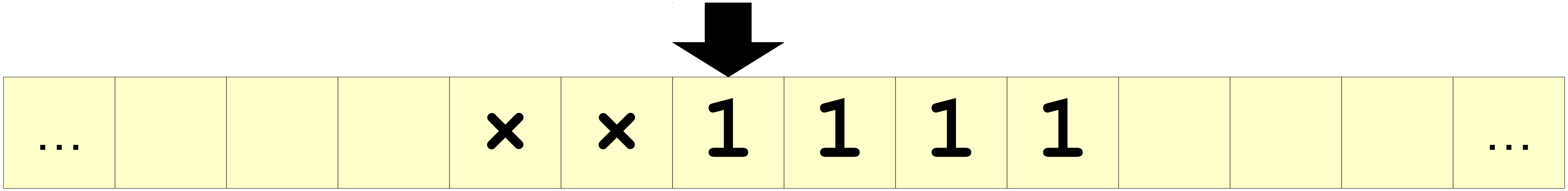
One Solution



One Solution

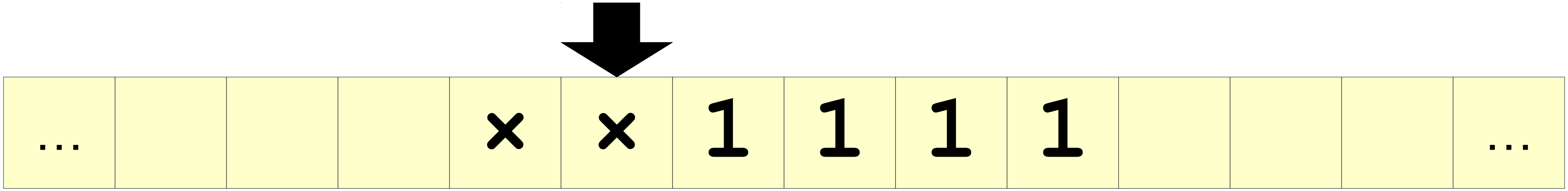


One Solution



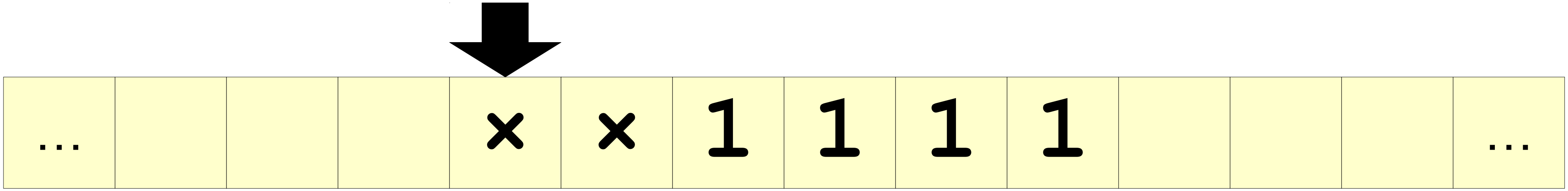
…				×	×	1	1	1	1				…

One Solution



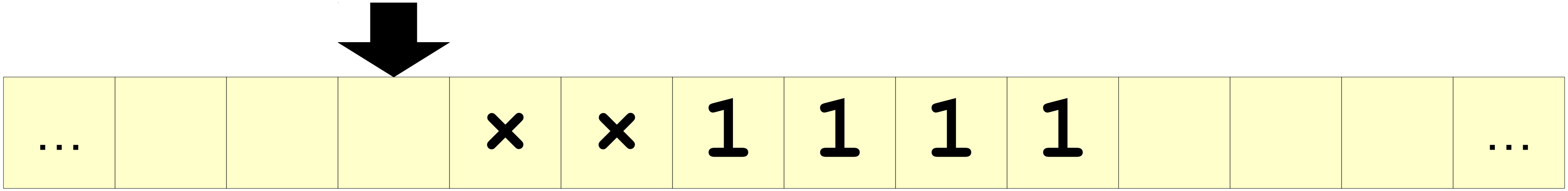
…				×	×	1	1	1	1				…

One Solution



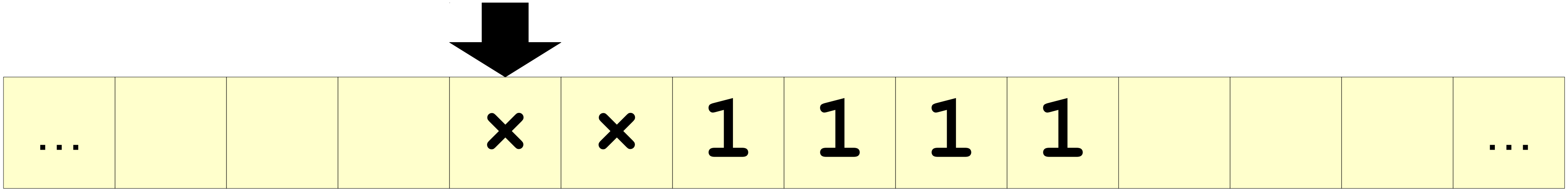
…				×	×	1	1	1	1				…

One Solution

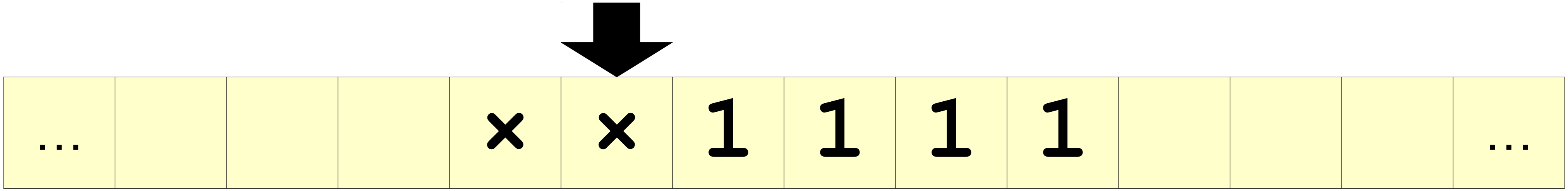


…				×	×	1	1	1	1				…

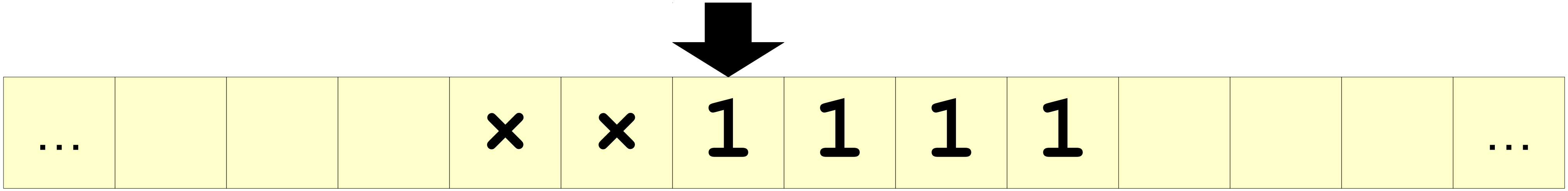
One Solution



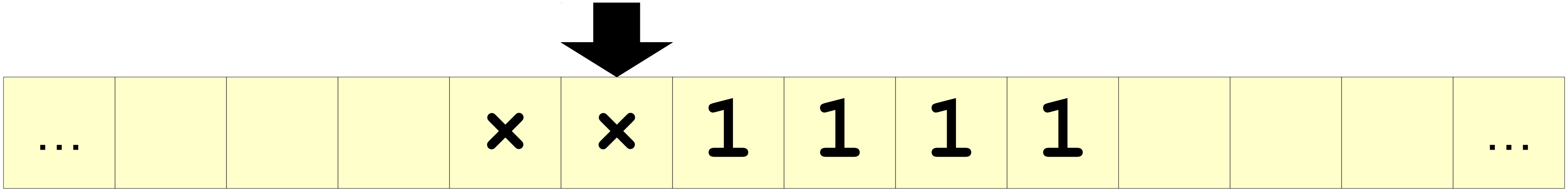
One Solution



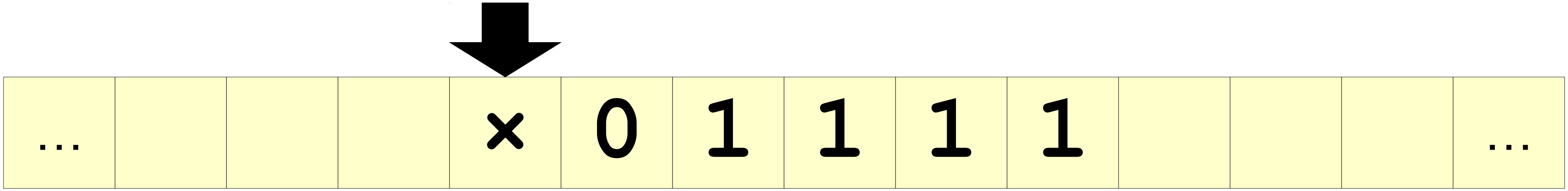
One Solution



One Solution

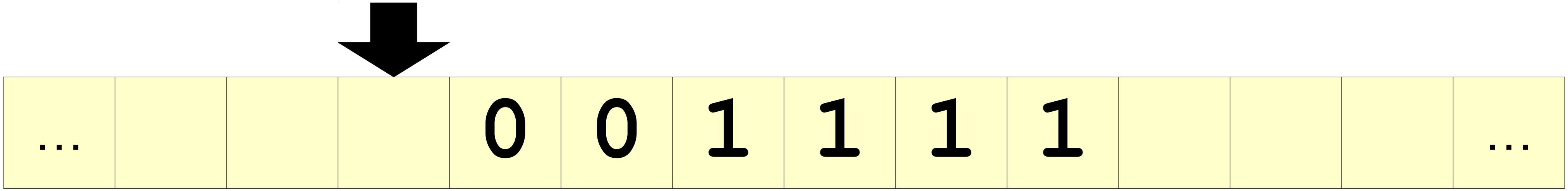


One Solution

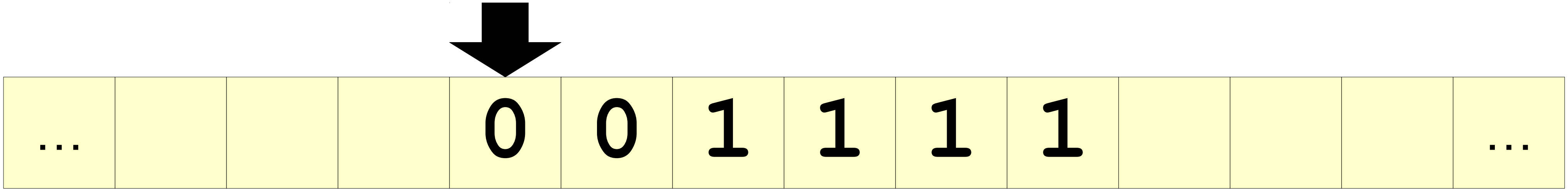


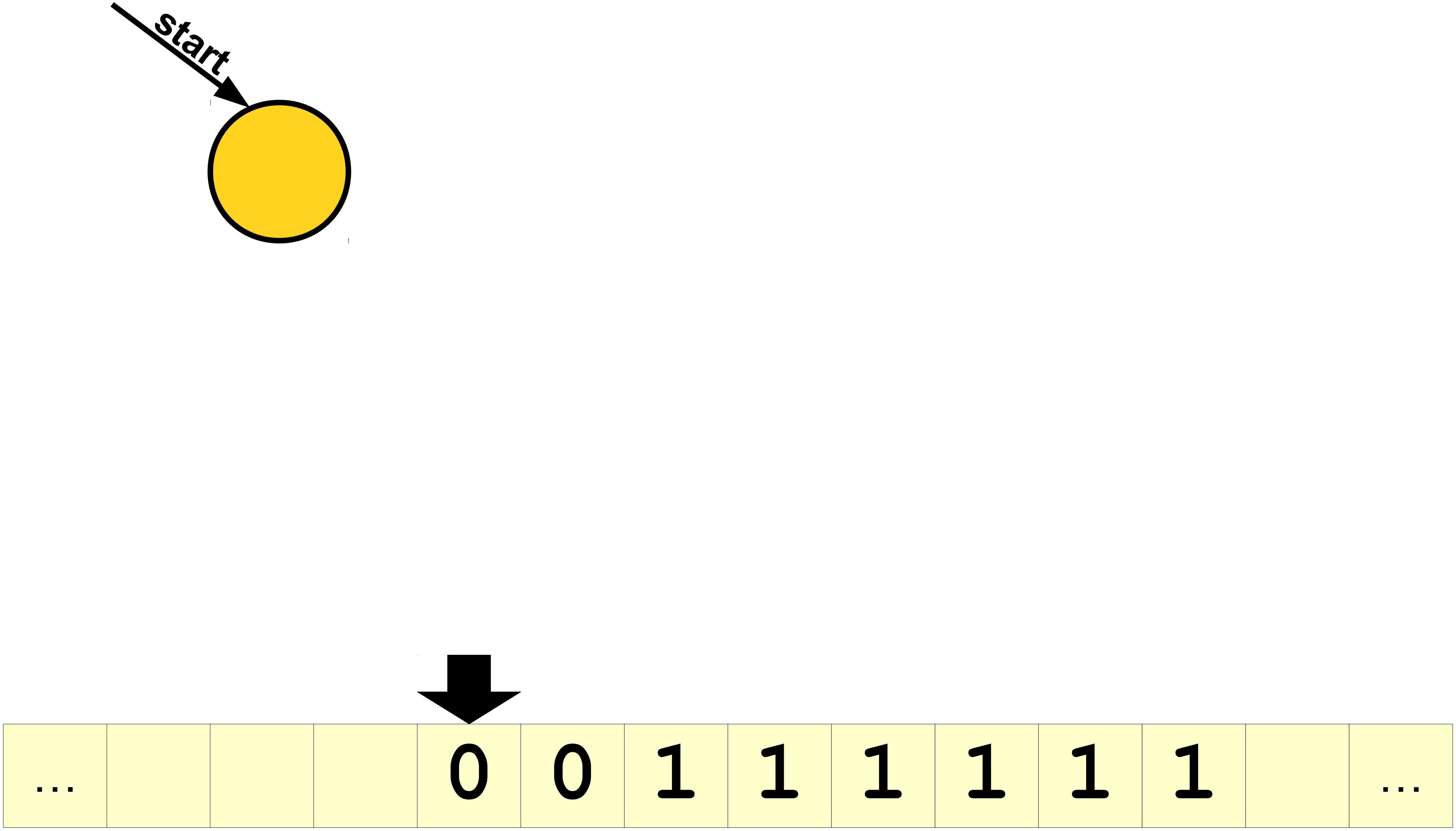
…				×	0	1	1	1	1				…

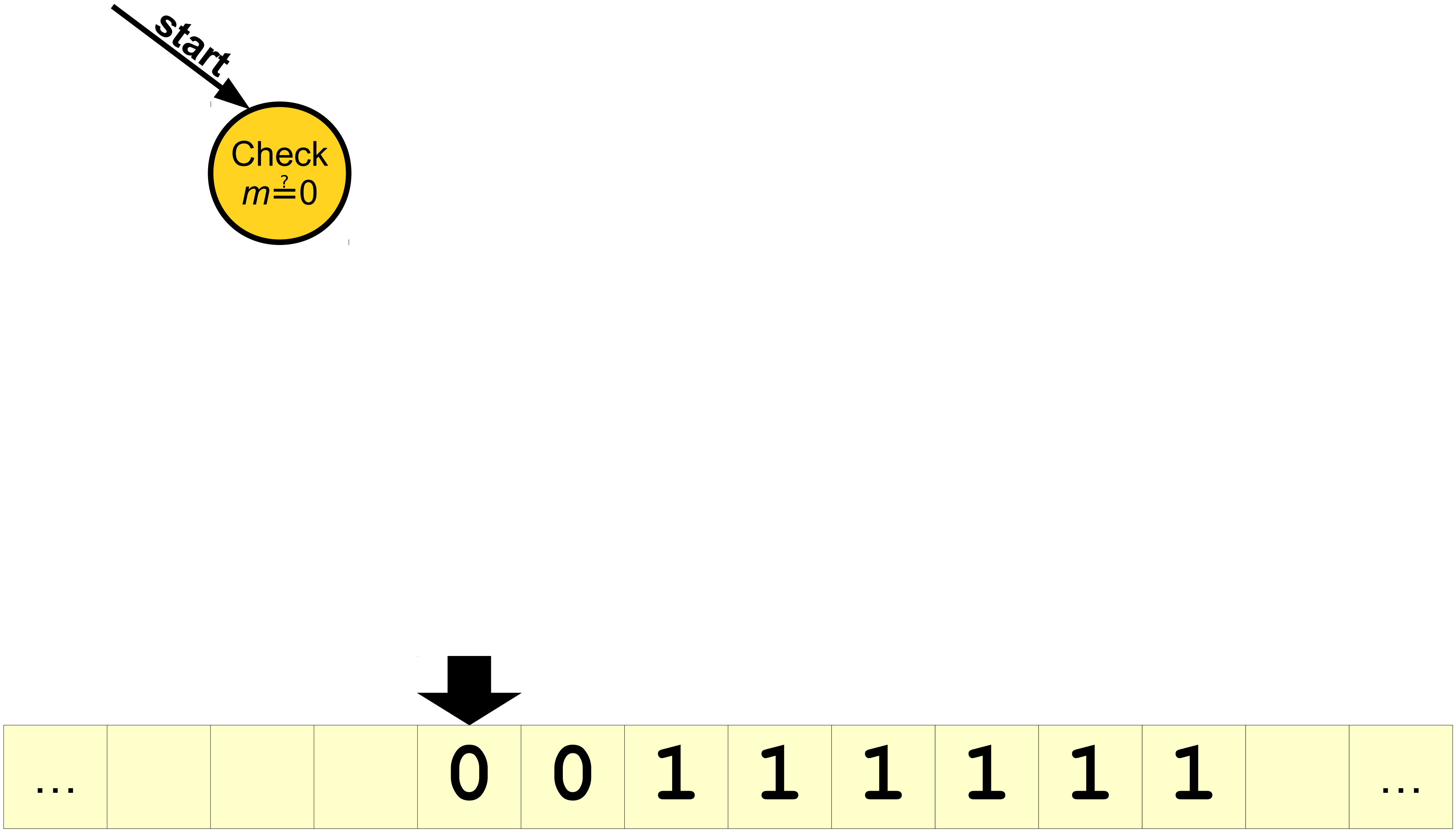
One Solution

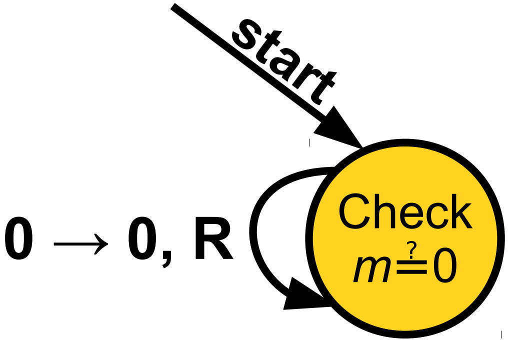


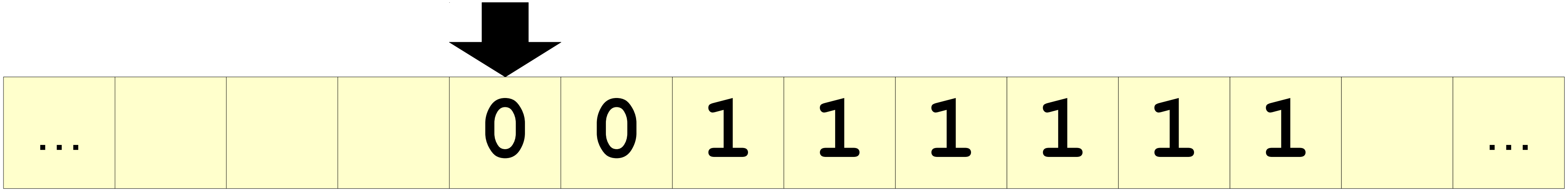
One Solution

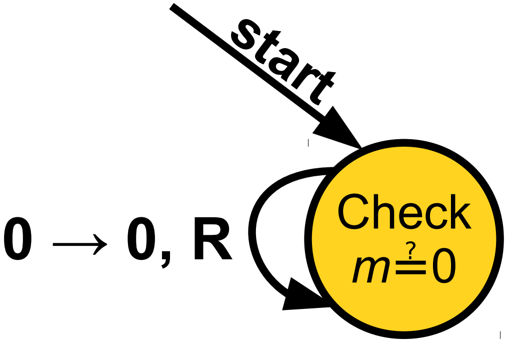


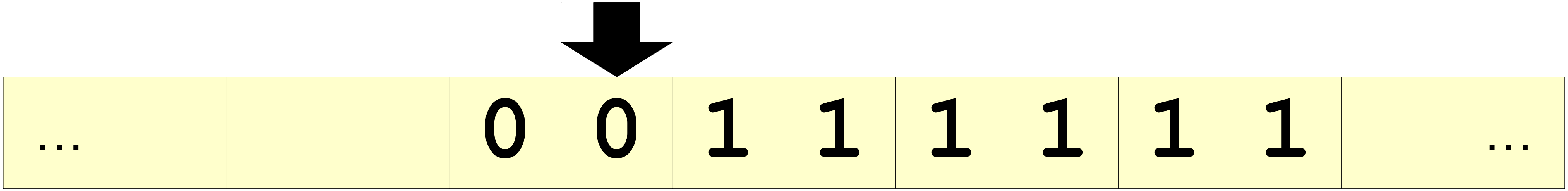

start
…
0
0
1
1
1
1
1
1
…


start
Check
$m \overset{?}{=} 0$
…
0
0
1
1
1
1
1
1
…

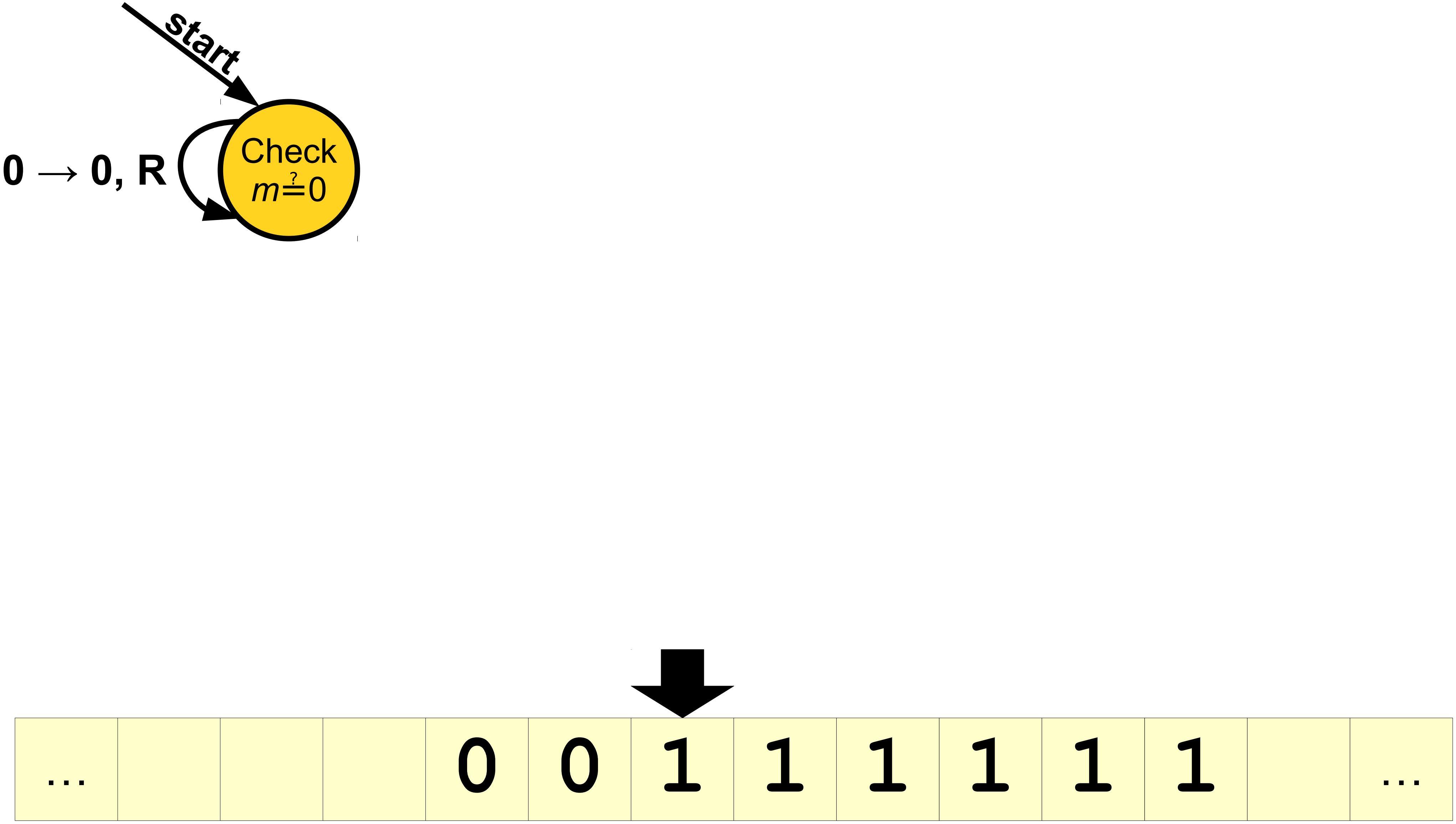

start
0 → 0, R
Check
$m \overset{?}{=} 0$


…
0
0
1
1
1
1
1
1
…

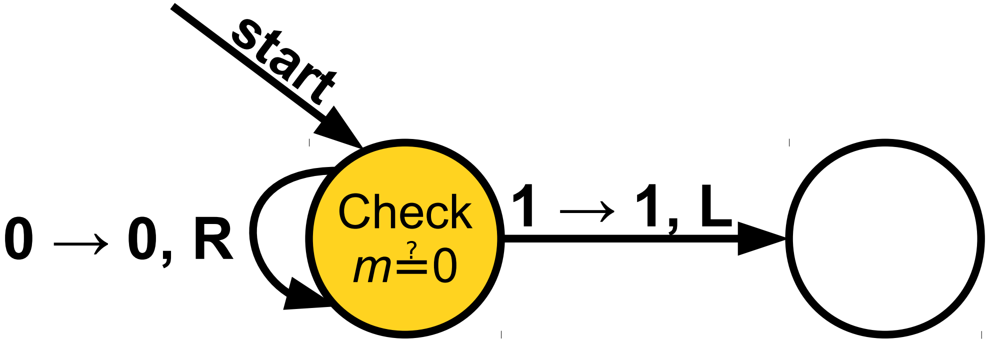


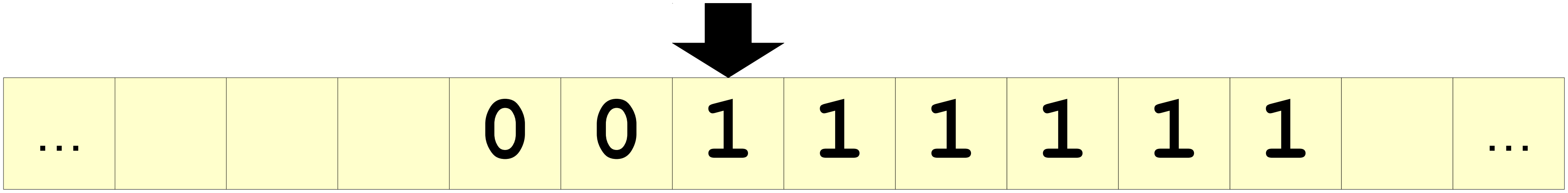


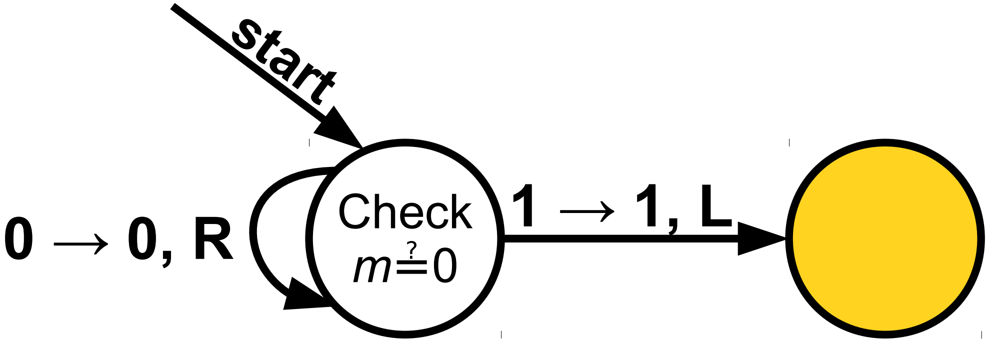
…				0	0	1	1	1	1	1	1		…

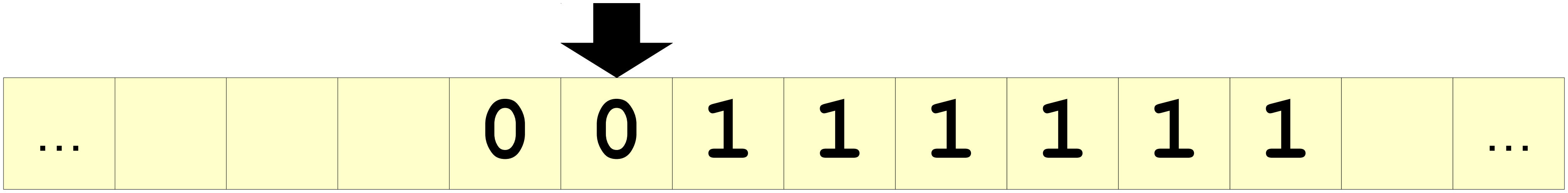


…				0	0	1	1	1	1	1	1		…

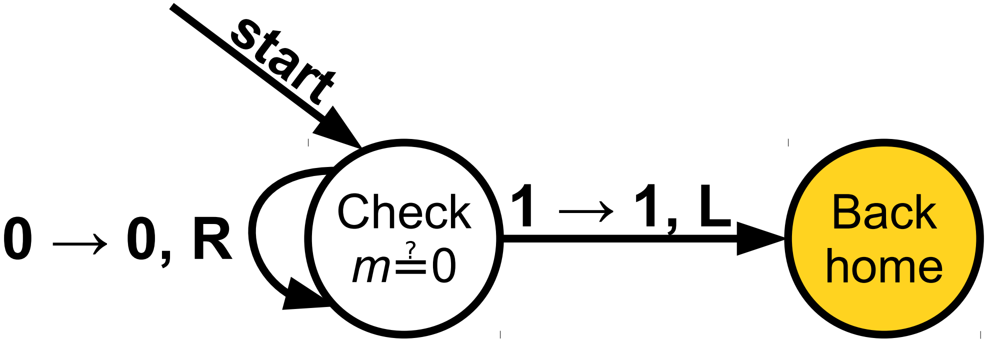

start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L

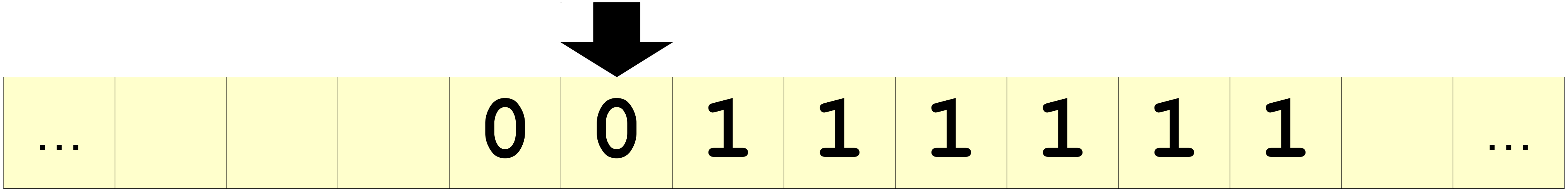

…
0
0
1
1
1
1
1
1
…

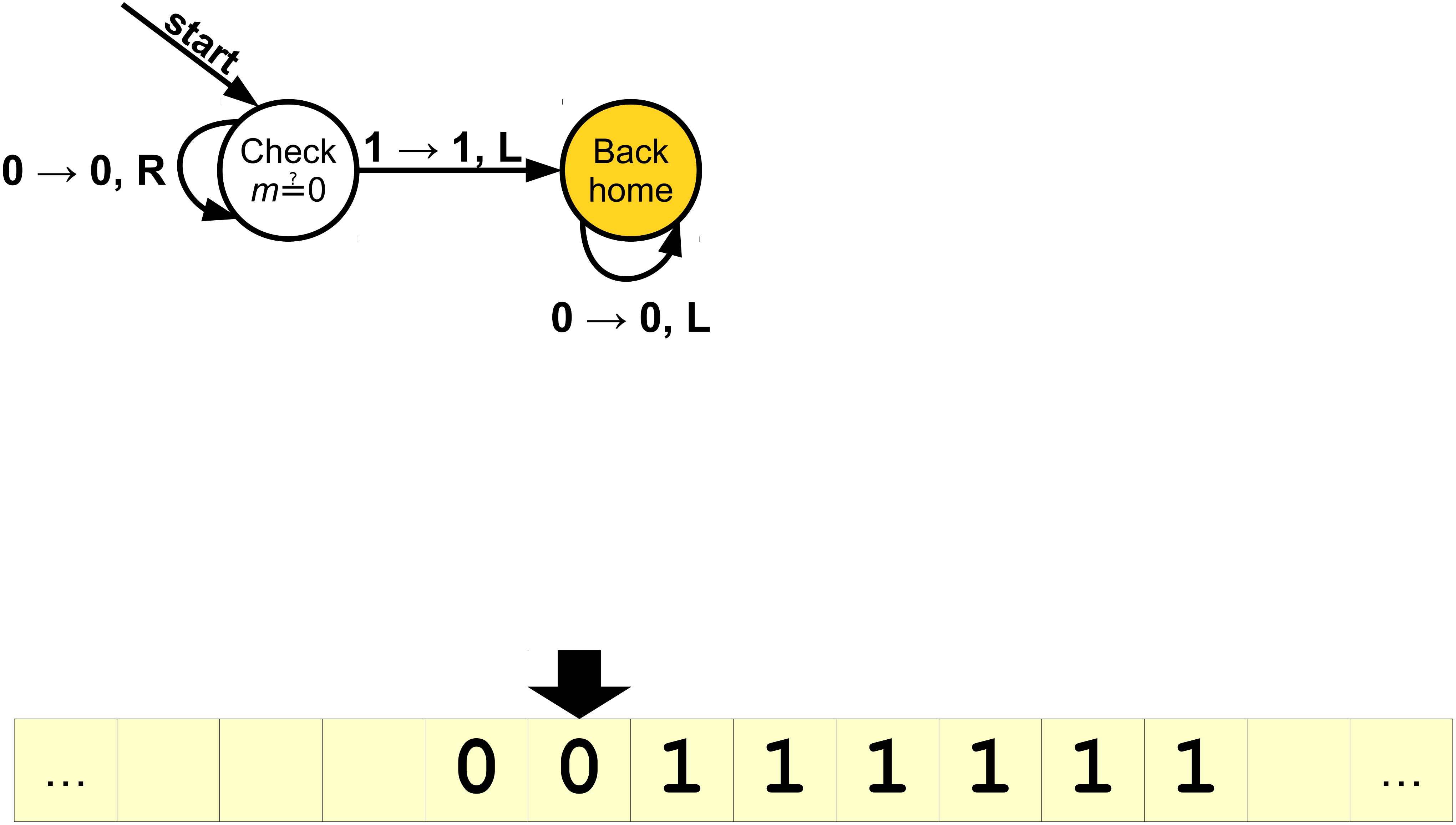


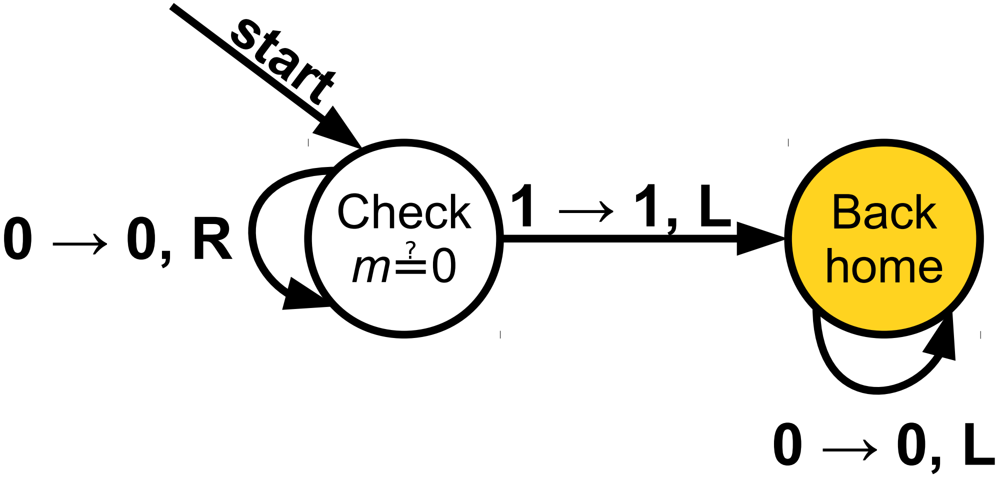


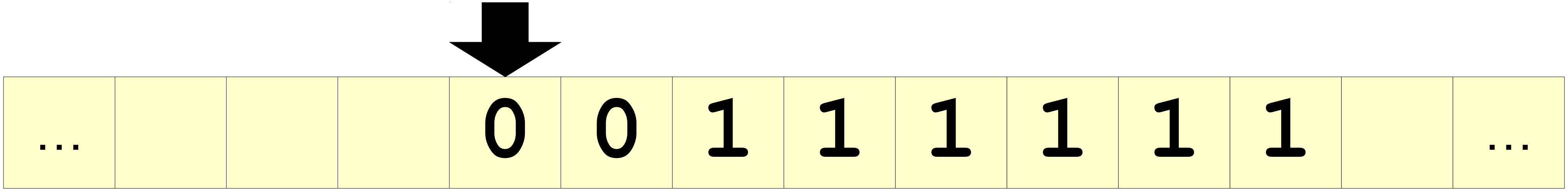
…				0	0	1	1	1	1	1	1		…


start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home

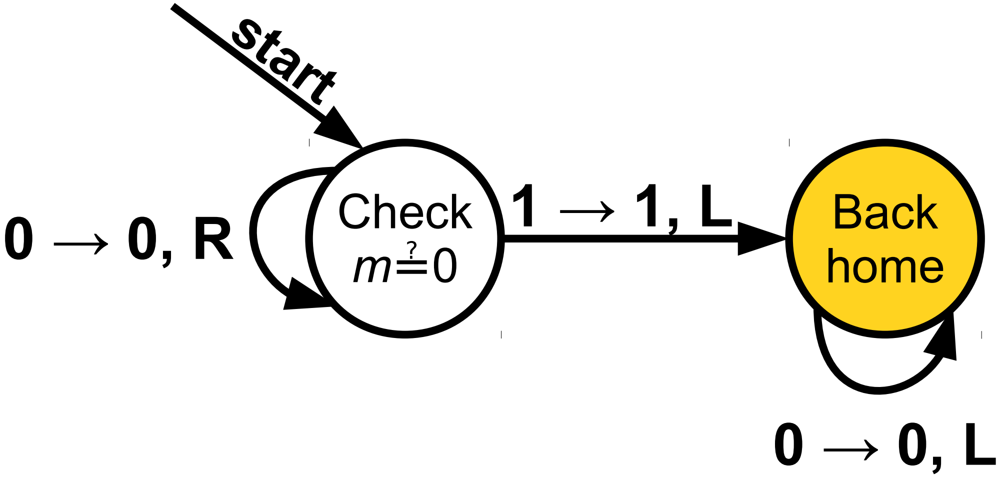

…
0
0
1
1
1
1
1
1
…

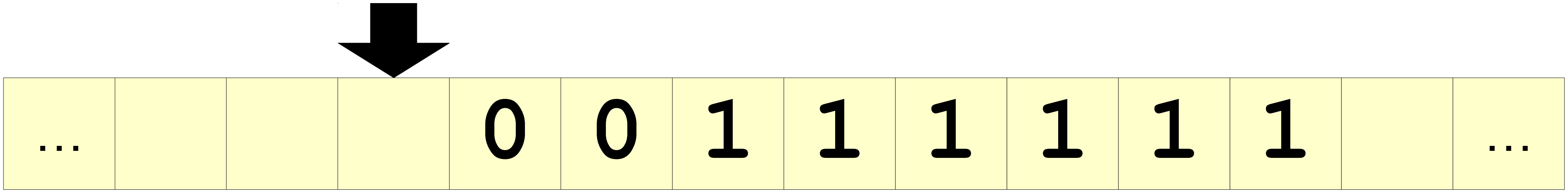

start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
0 → 0, L
…
0
0
1
1
1
1
1
1
…



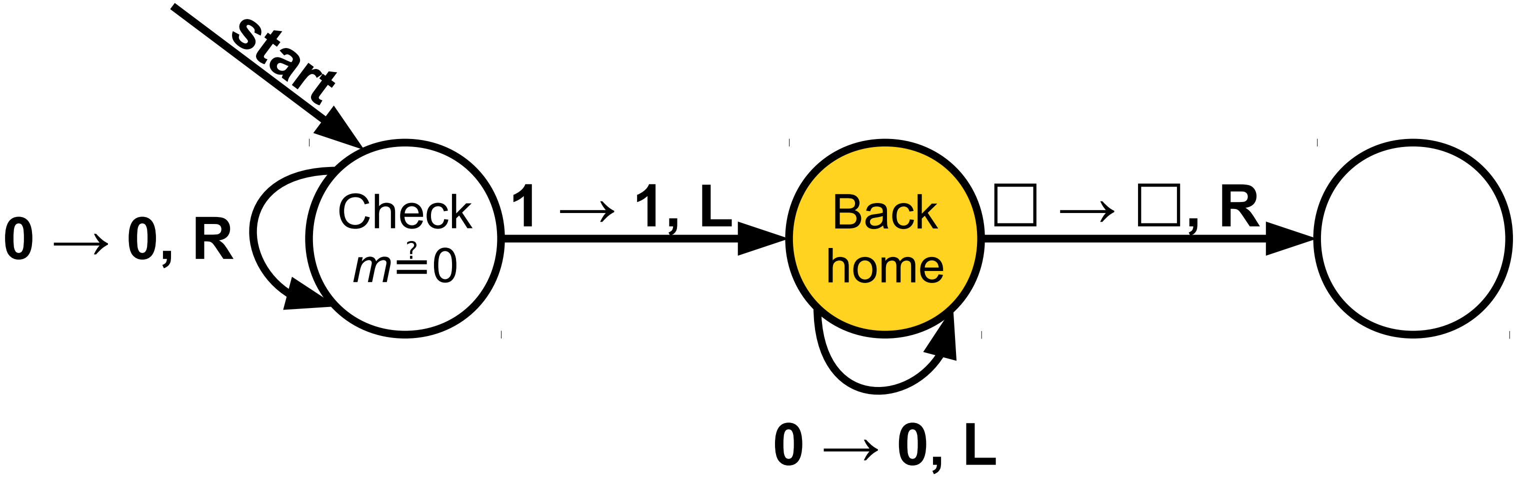


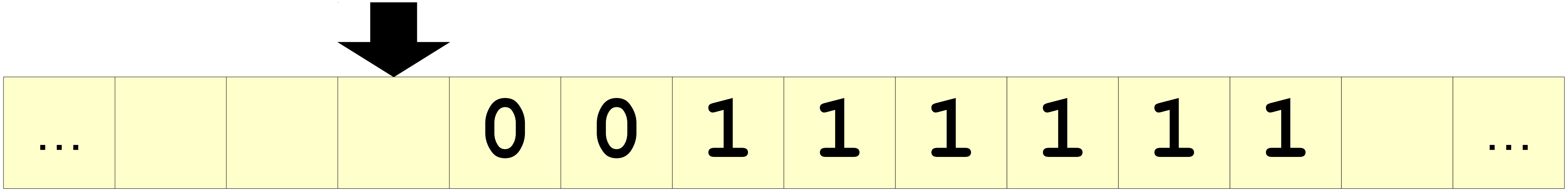
…				0	0	1	1	1	1	1	1		…



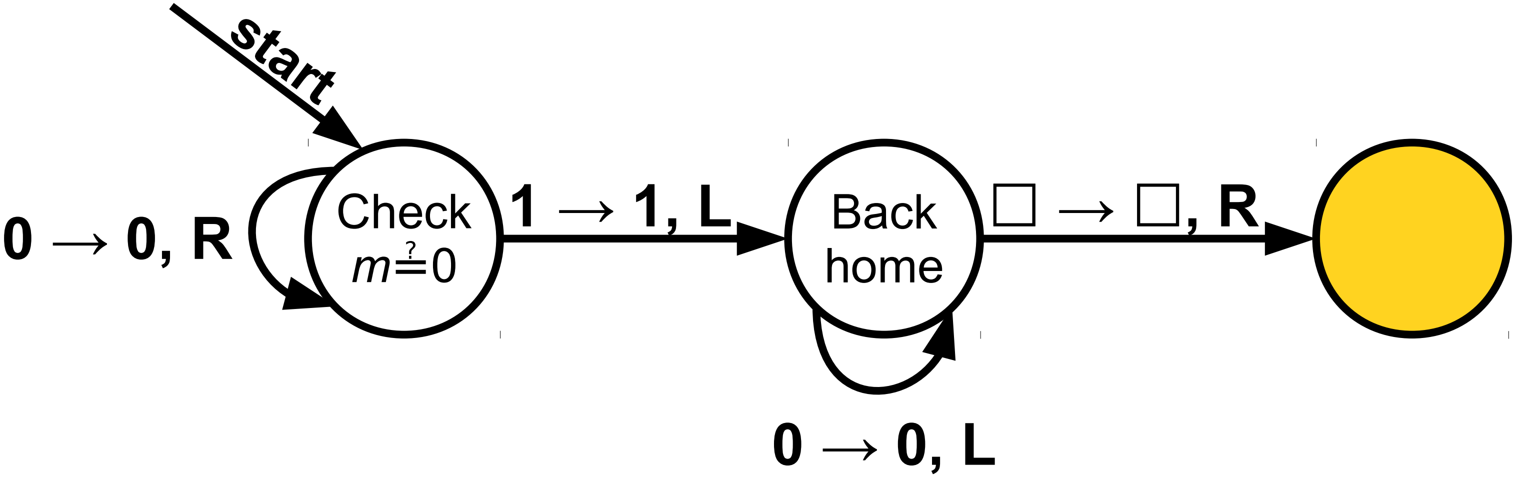


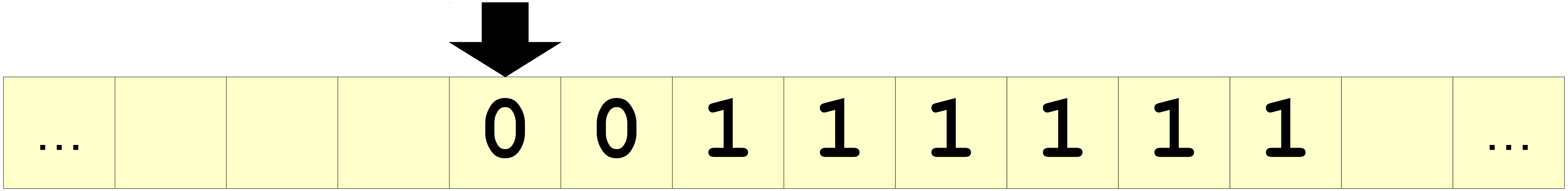
…				0	0	1	1	1	1	1	1		…



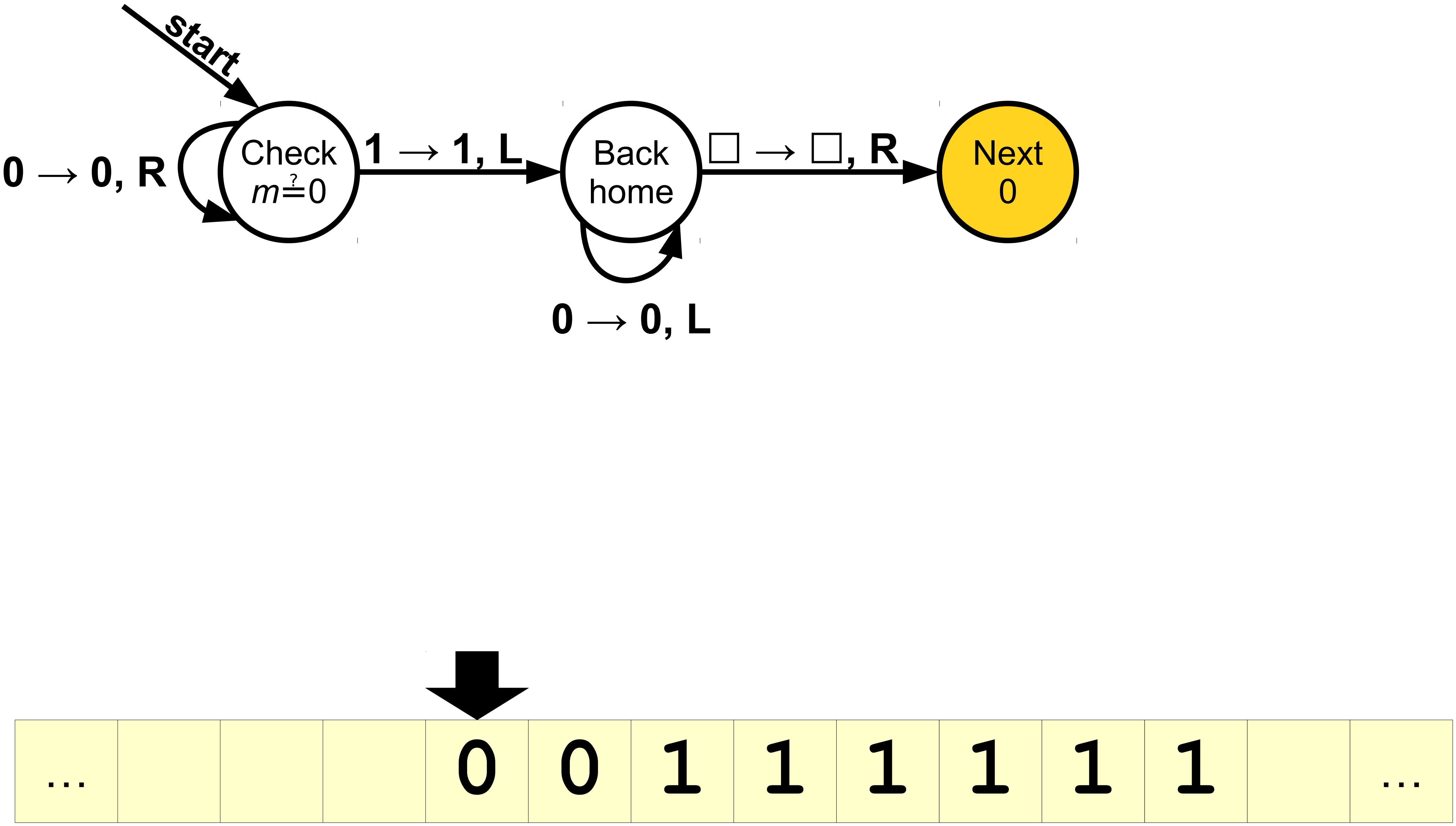


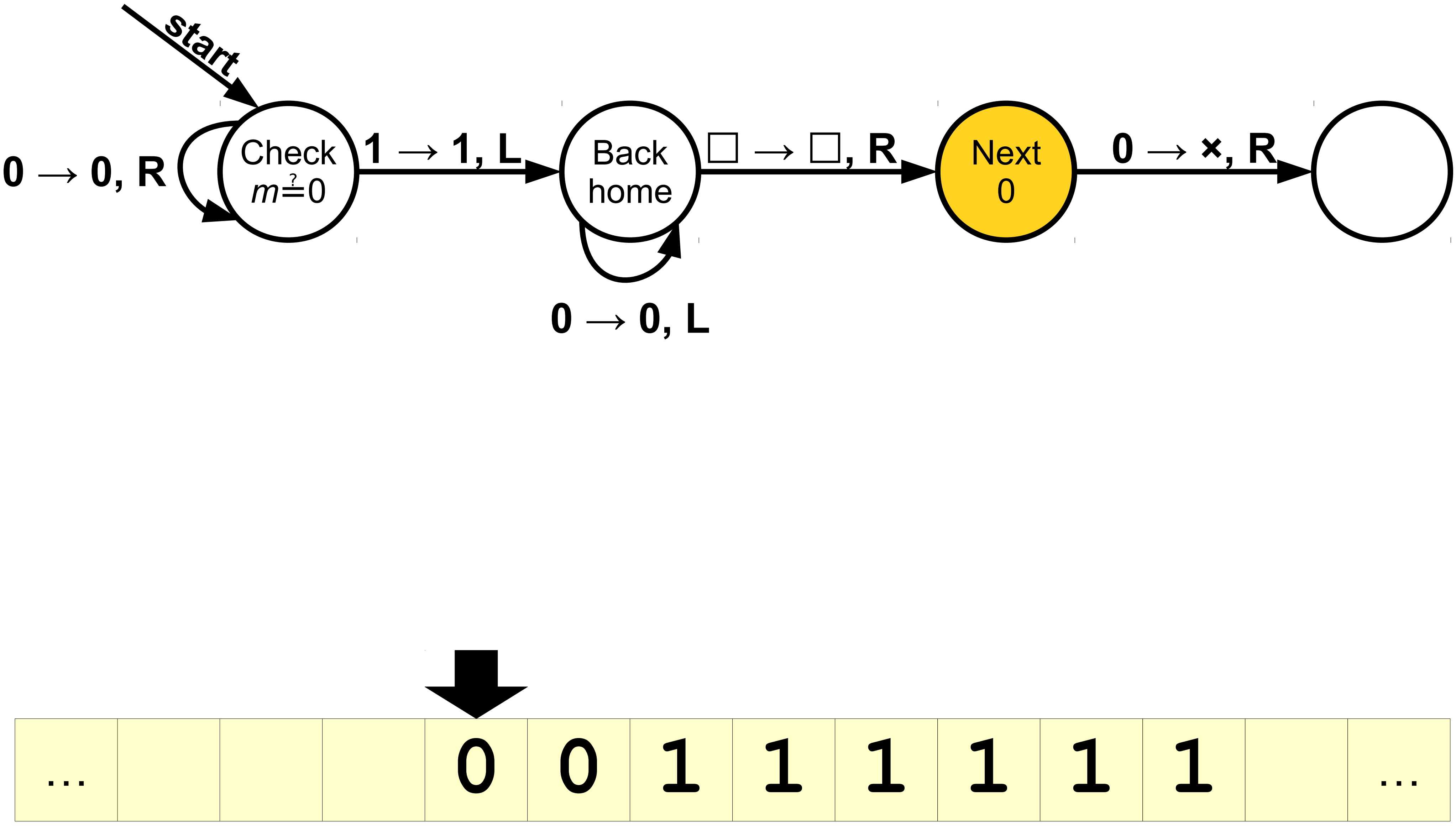
…				0	0	1	1	1	1	1	1		…

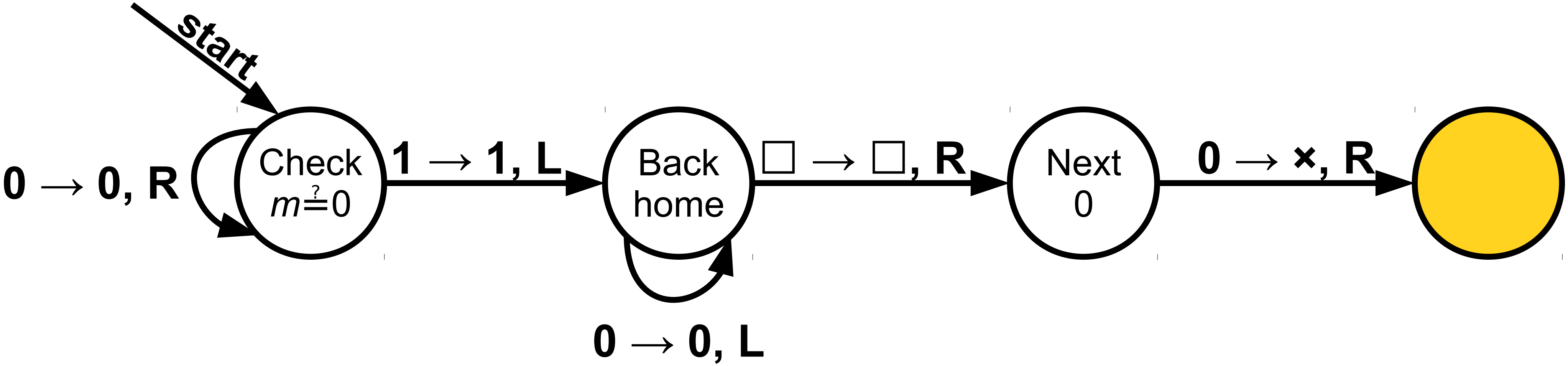


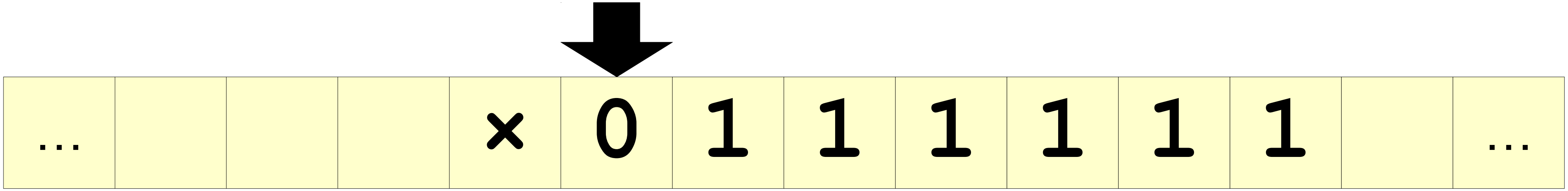


…				0	0	1	1	1	1	1	1		…

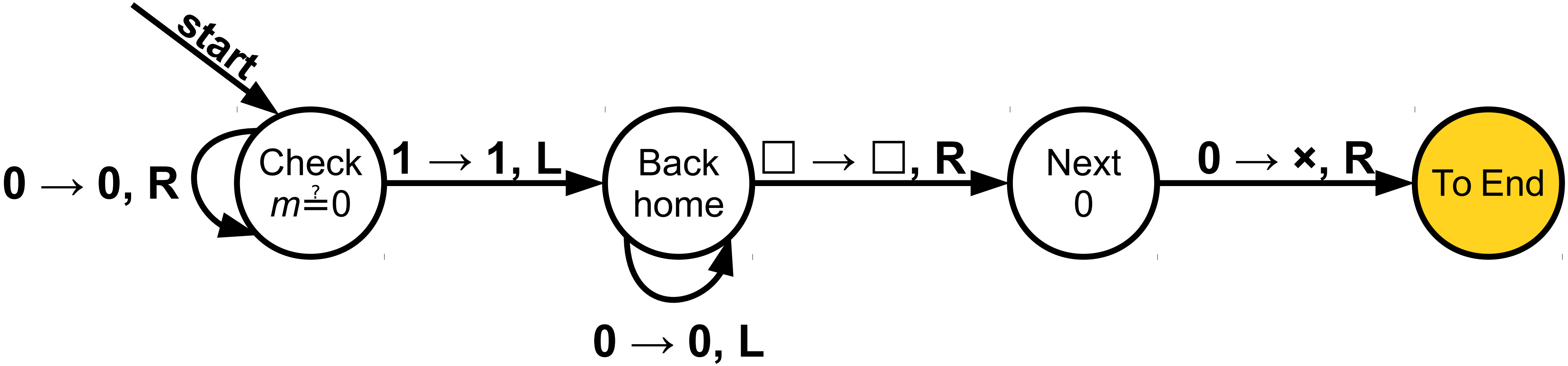

start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
…
0
0
1
1
1
1
1
1
…

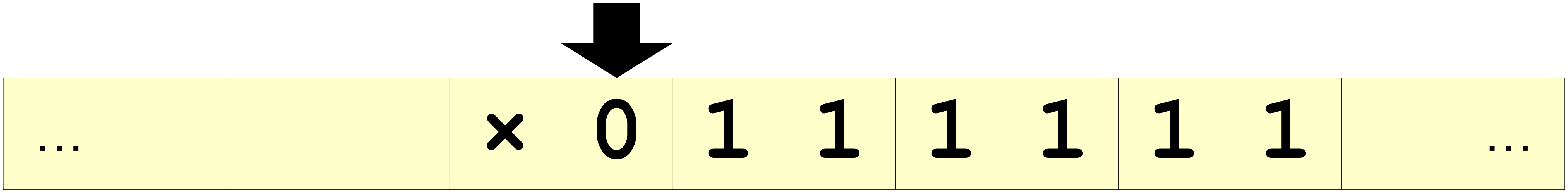

start
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
0 → ×, R
…
0
0
1
1
1
1
1
1
…



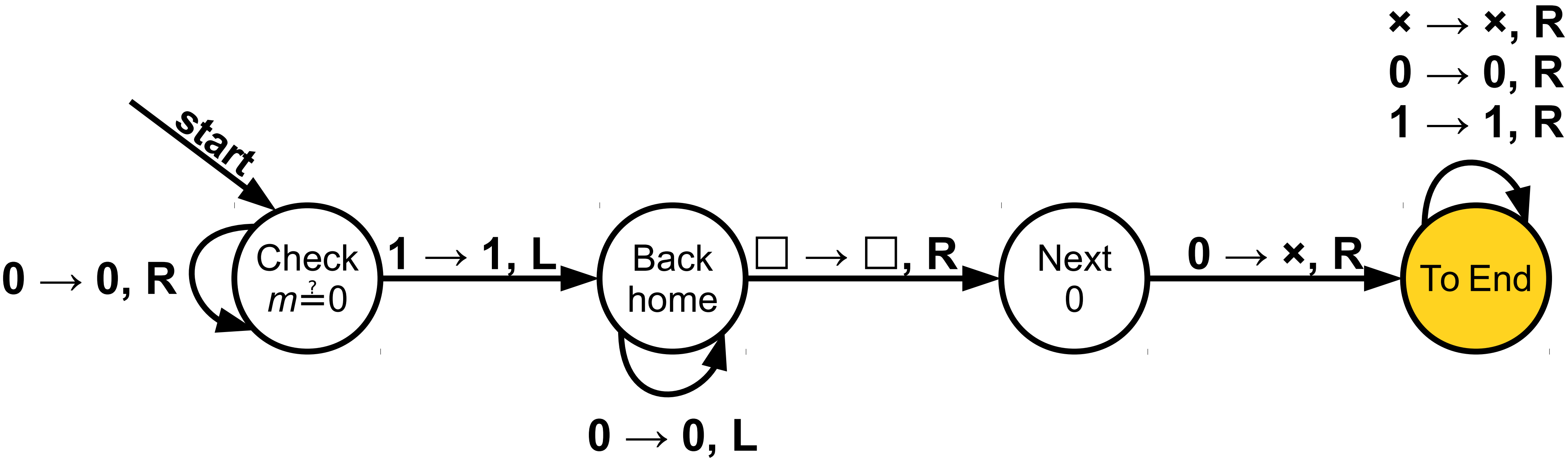


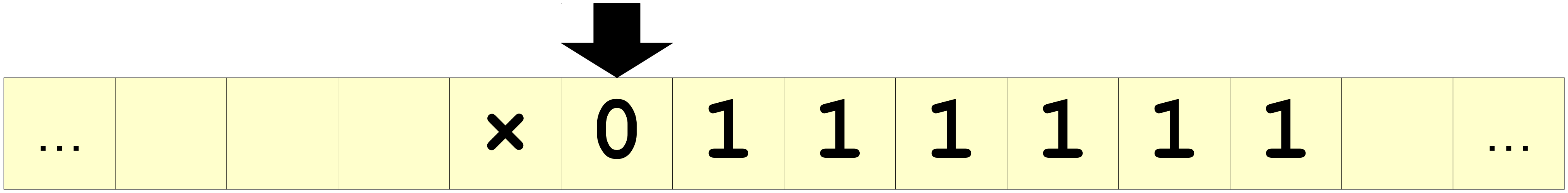
…				×	0	1	1	1	1	1	1		…



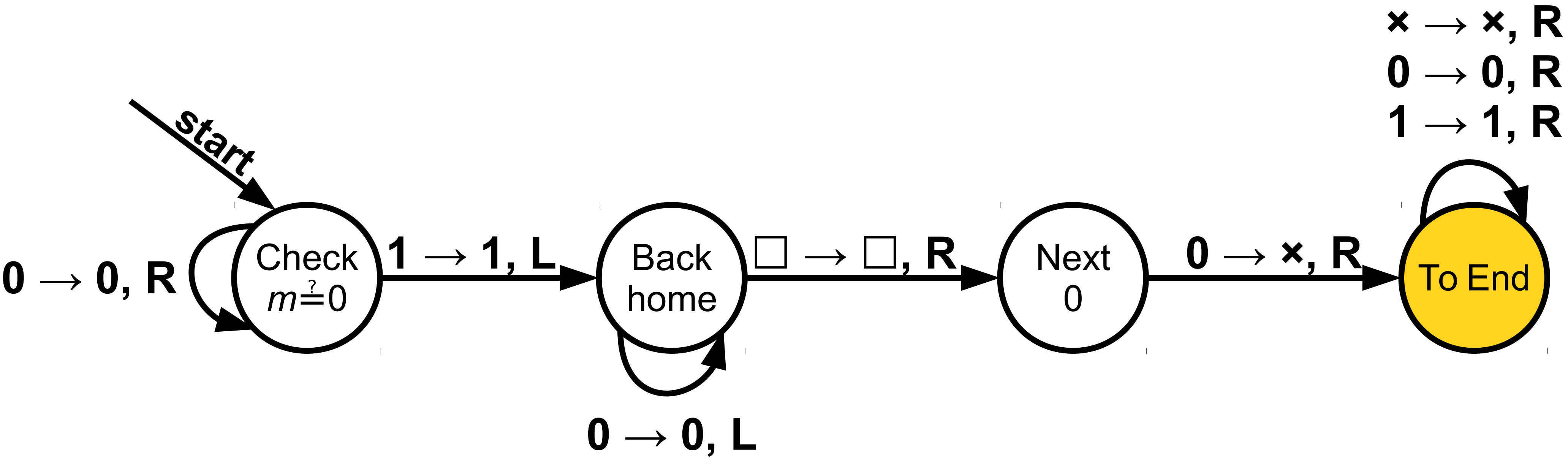


…				×	0	1	1	1	1	1	1		…


start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R

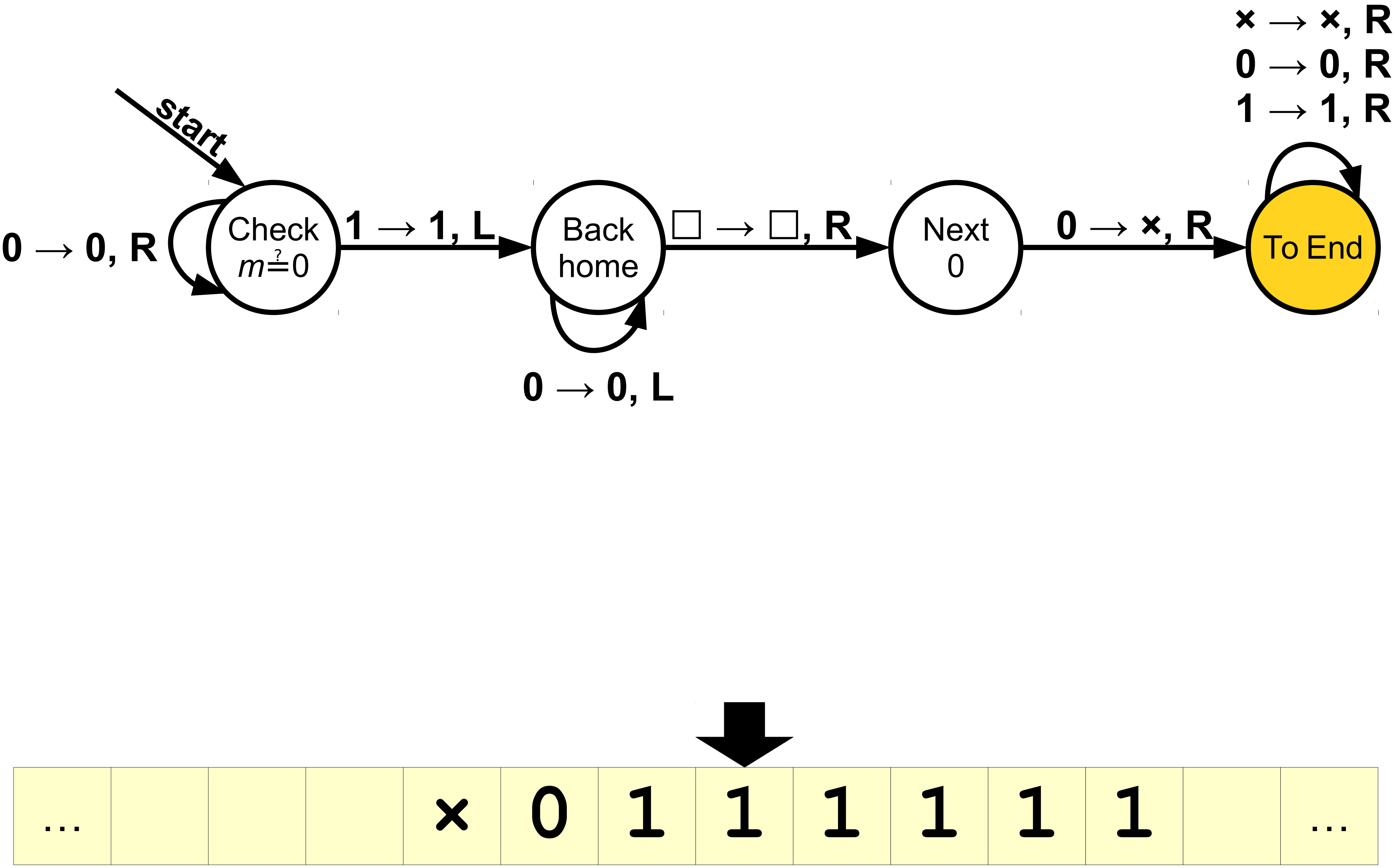


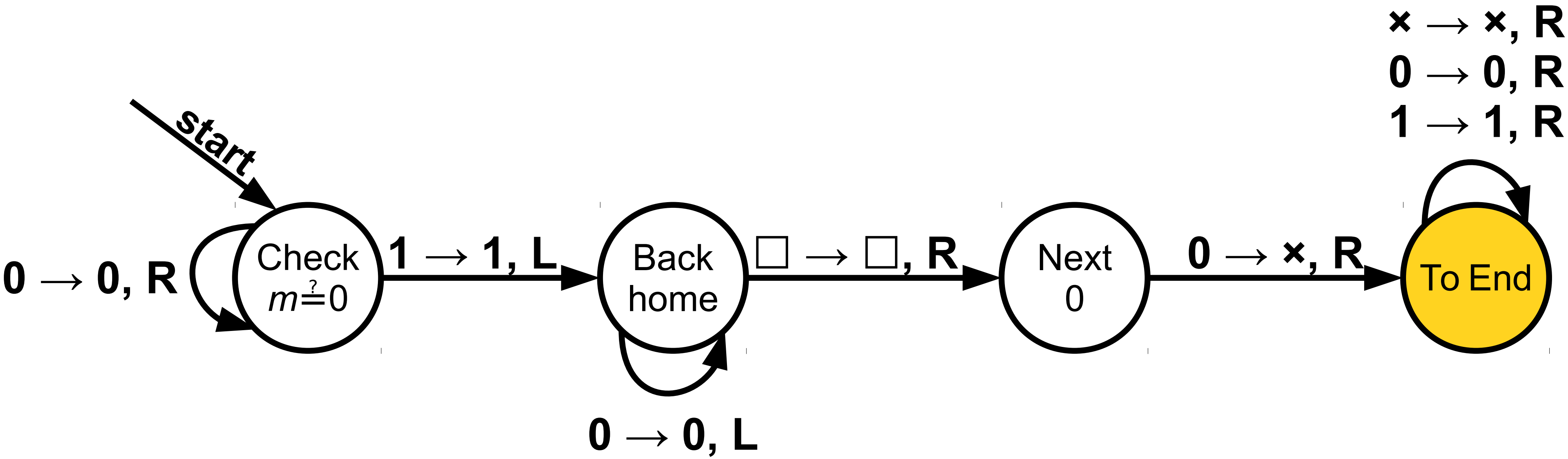
…				×	0	1	1	1	1	1	1		…

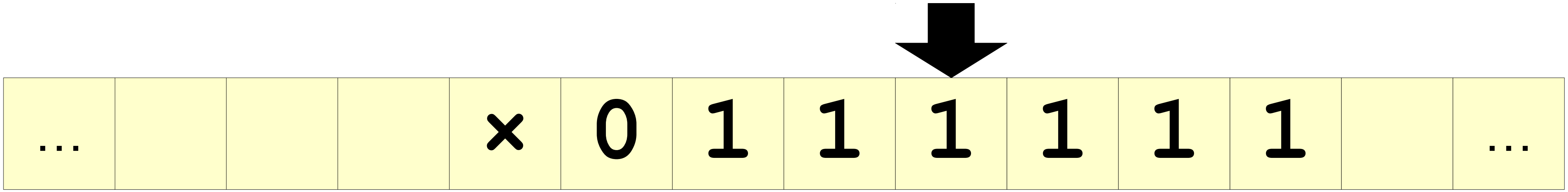


start
Check
$m \overset{?}{=} 0$
$0 \rightarrow 0$, R
$1 \rightarrow 1$, L
Back
home
$0 \rightarrow 0$, L
$\square \rightarrow \square$, R
Next
0
$0 \rightarrow \times$, R
To End
$\times \rightarrow \times$, R
$0 \rightarrow 0$, R
$1 \rightarrow 1$, R

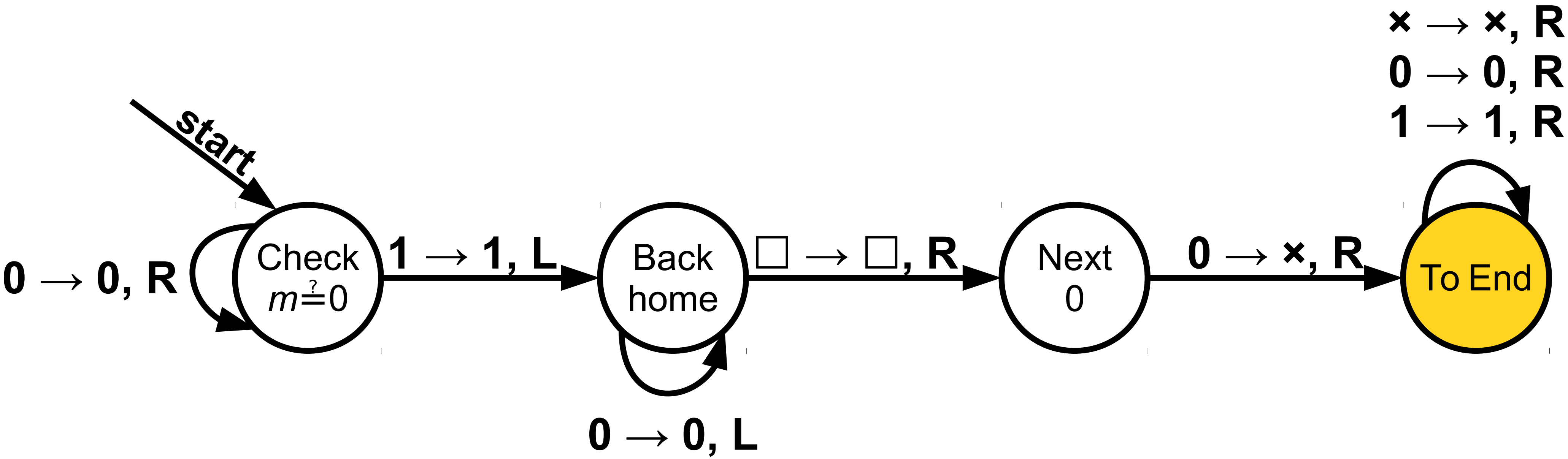
…				×	0	1	1	1	1	1	1		…


start
0 → 0, R
Check
m ≟ 0
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
…
×
0
1
1
1
1
1
1
…

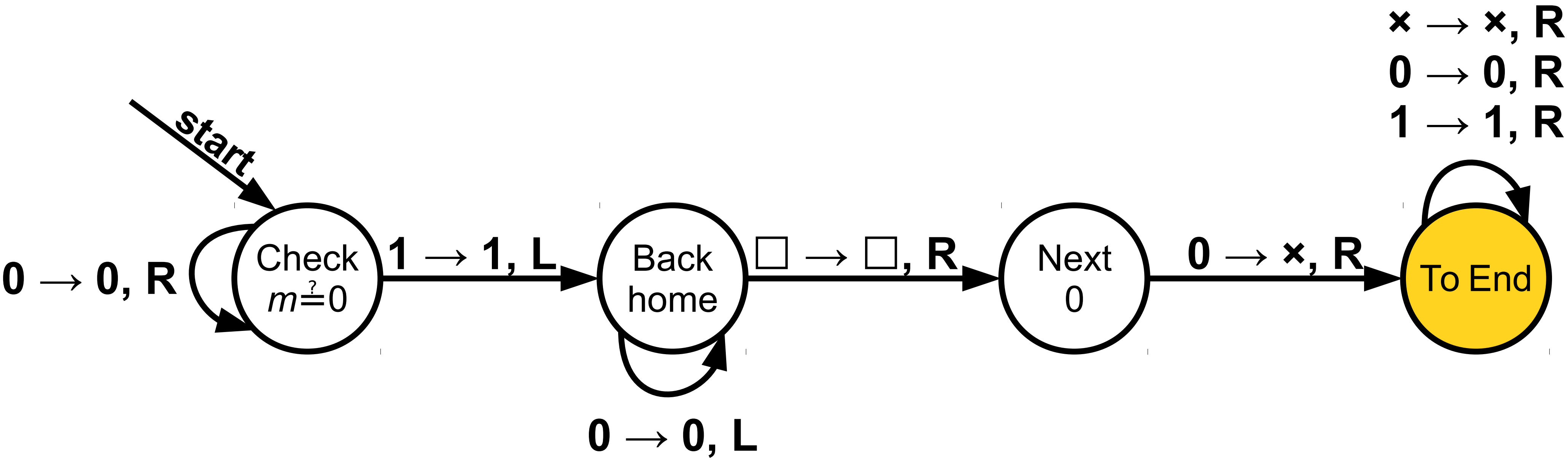

start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End

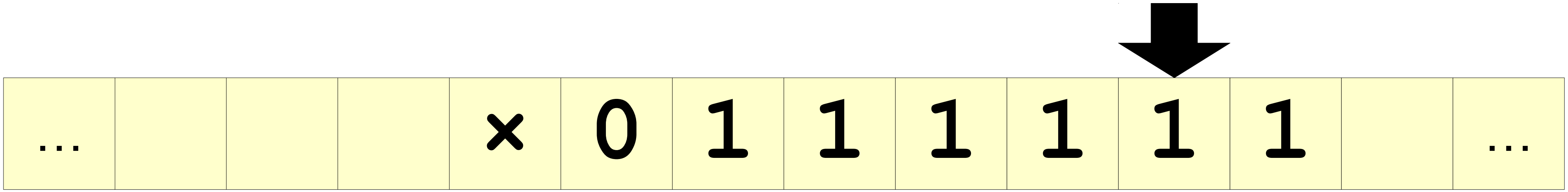


…				×	0	1	1	1	1	1	1		…

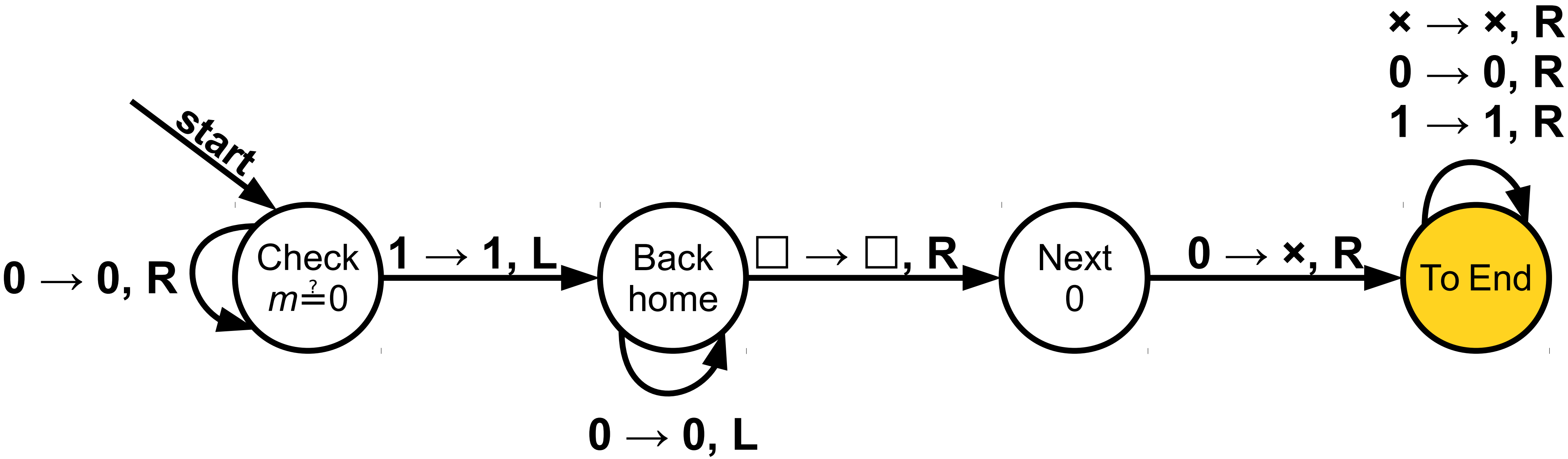

start
0 → 0, R
Check $m \overset{?}{=} 0$
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R

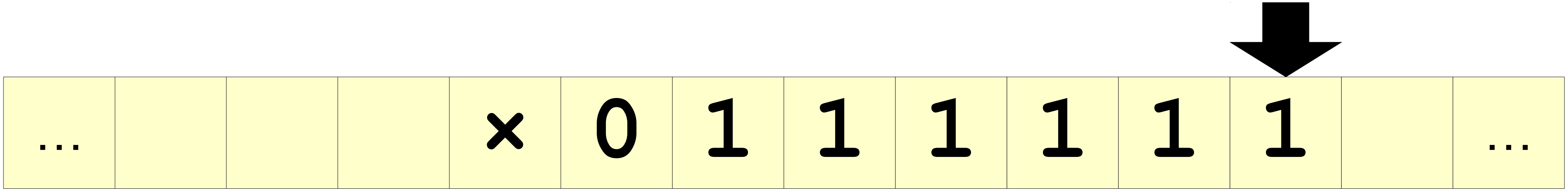
									↓				
…				×	0	1	1	1	1	1	1		…



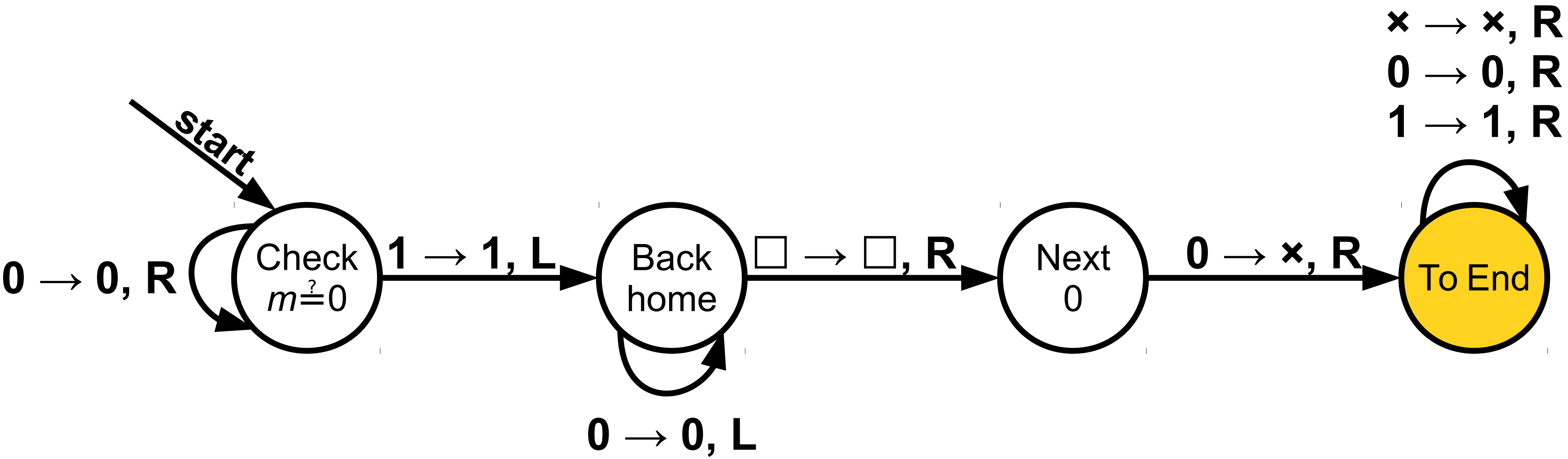


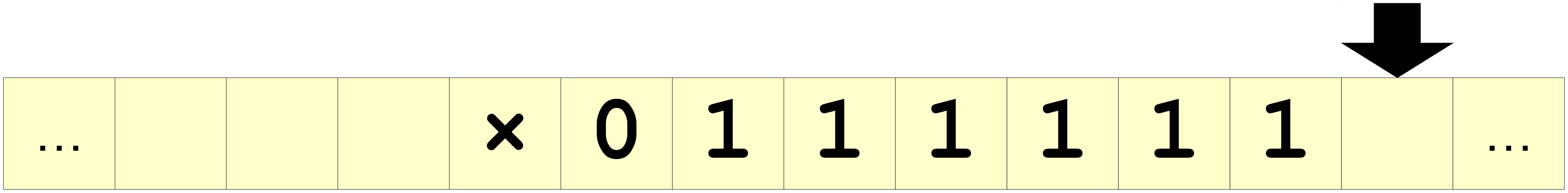
…				×	0	1	1	1	1	1	1		…

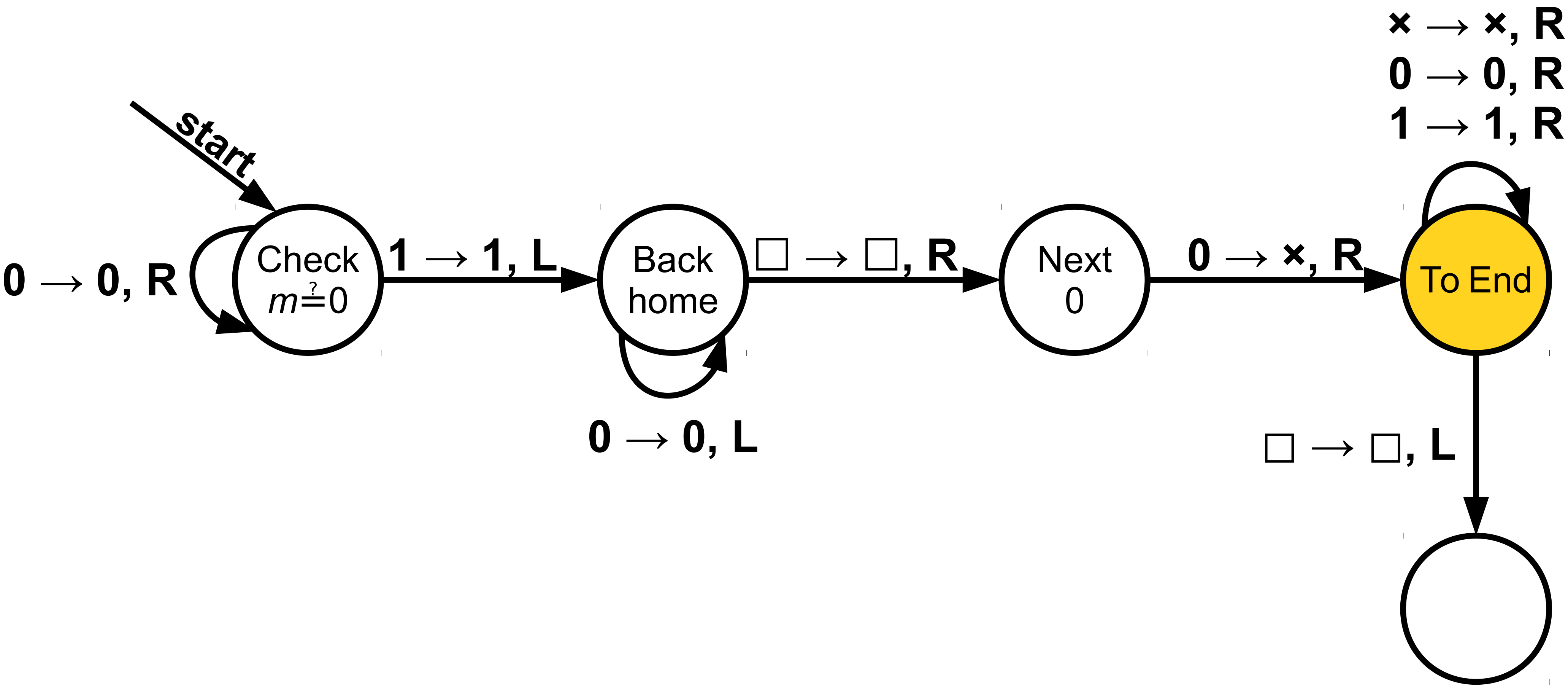

start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End



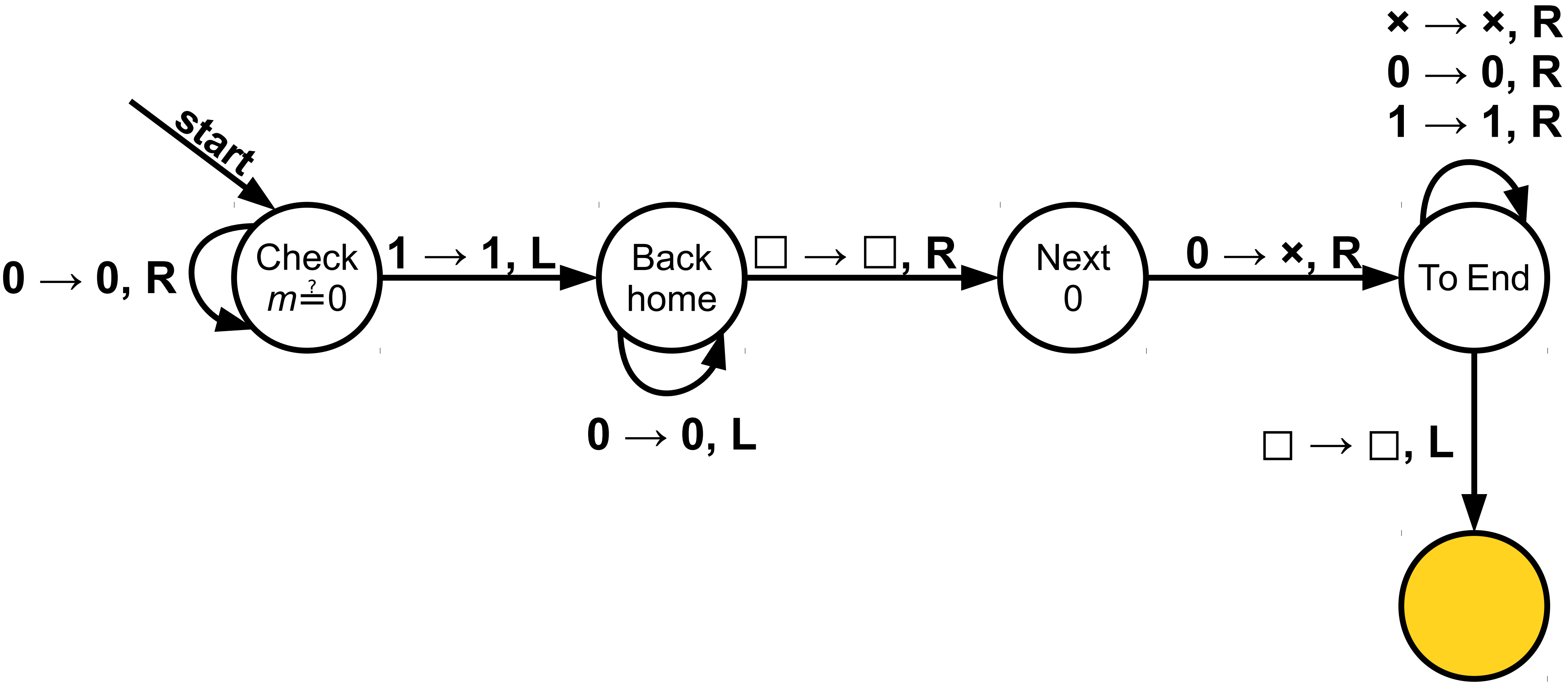
…				×	0	1	1	1	1	1	1		…

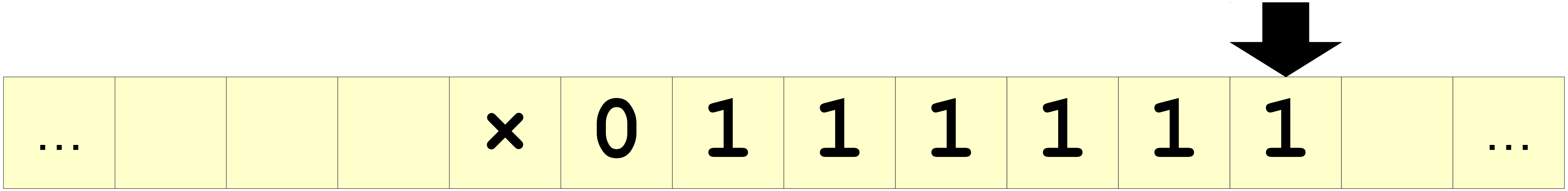

start
0 → 0, R
Check
m ≟ 0
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R


…
×
0
1
1
1
1
1
1
…

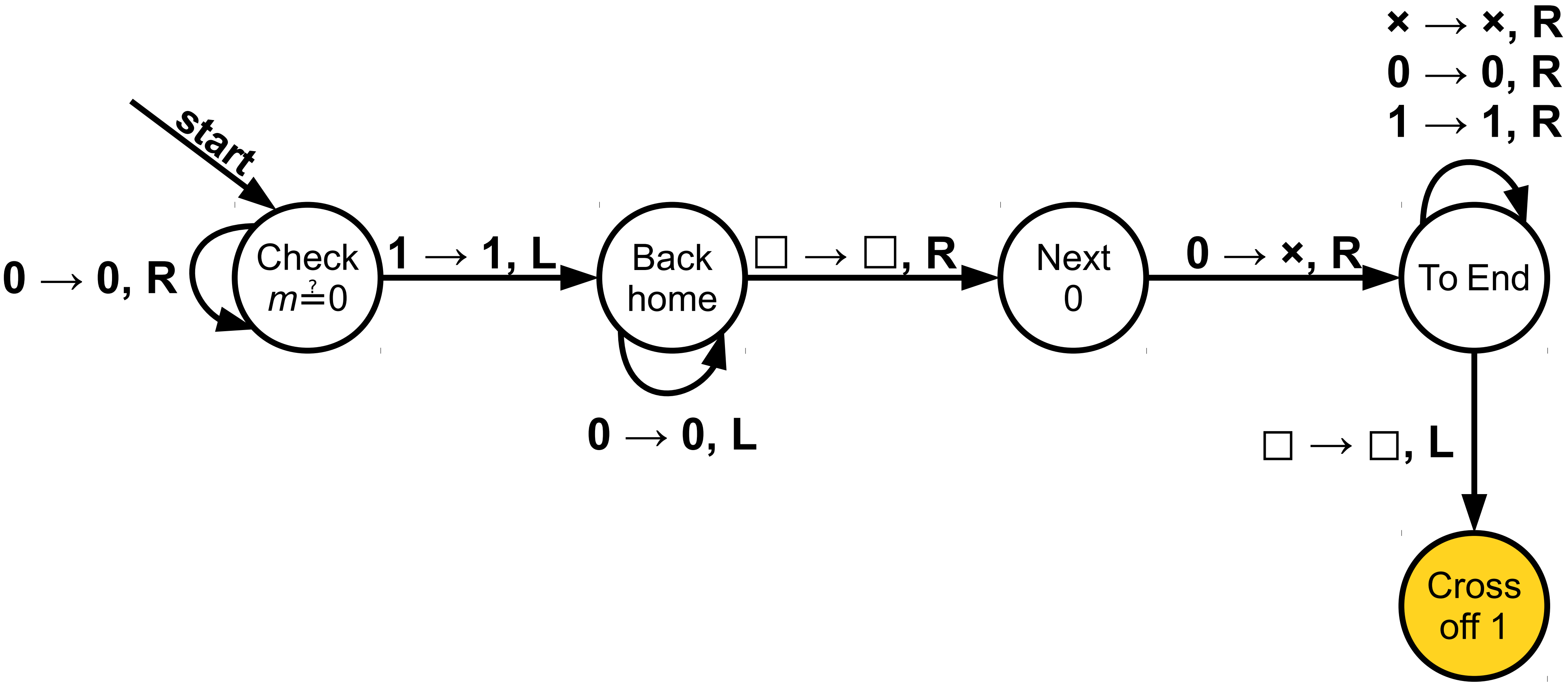

start
0 → 0, R
Check
$m\overset{?}{=}0$
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L

…				×	0	1	1	1	1	1	1		…

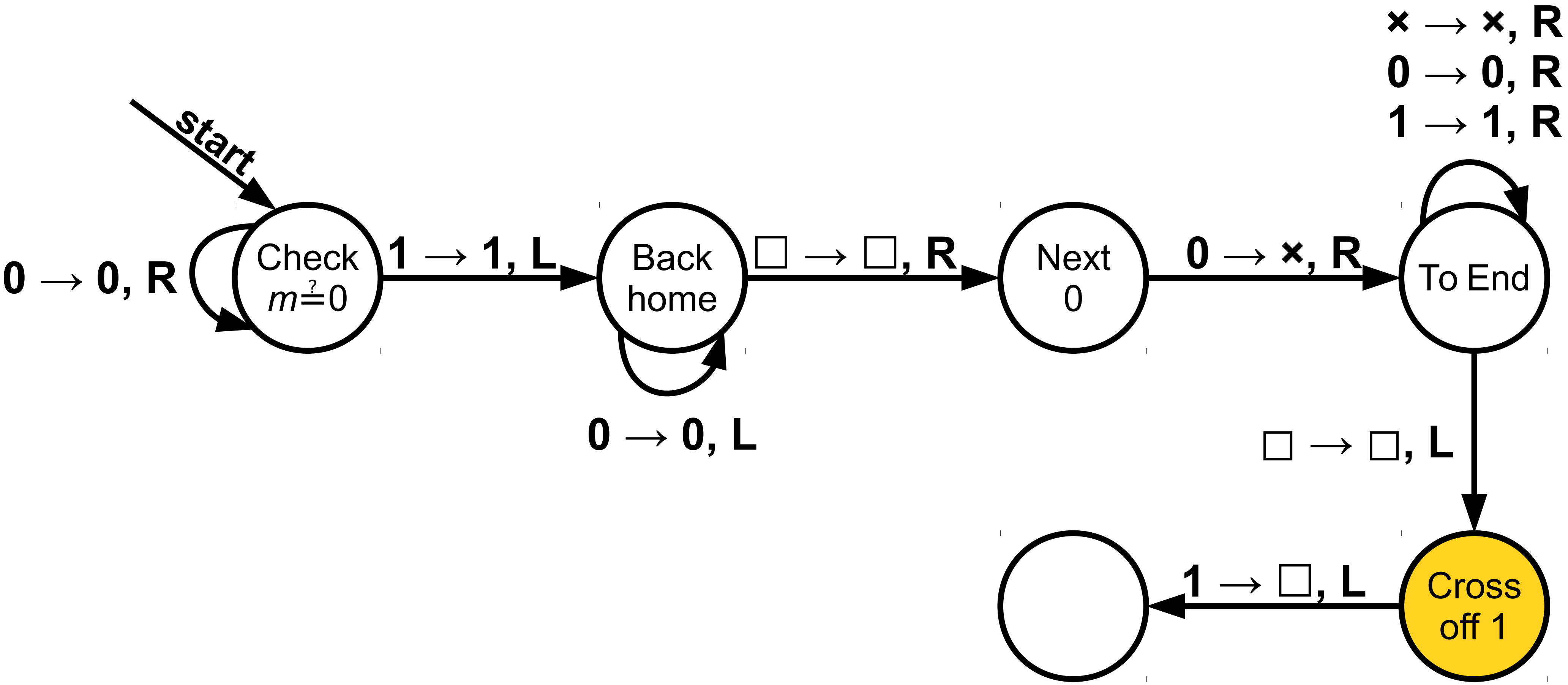

start
Check
$m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L



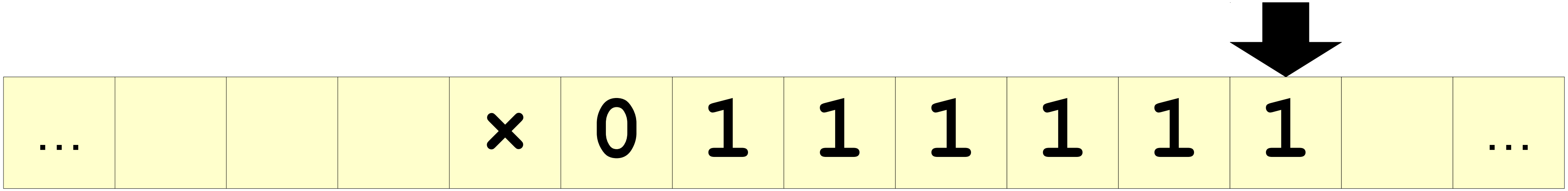
…				×	0	1	1	1	1	1	1		…


× → ×, R
0 → 0, R
1 → 1, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
0 → ×, R
To End
□ → □, L
Cross off 1

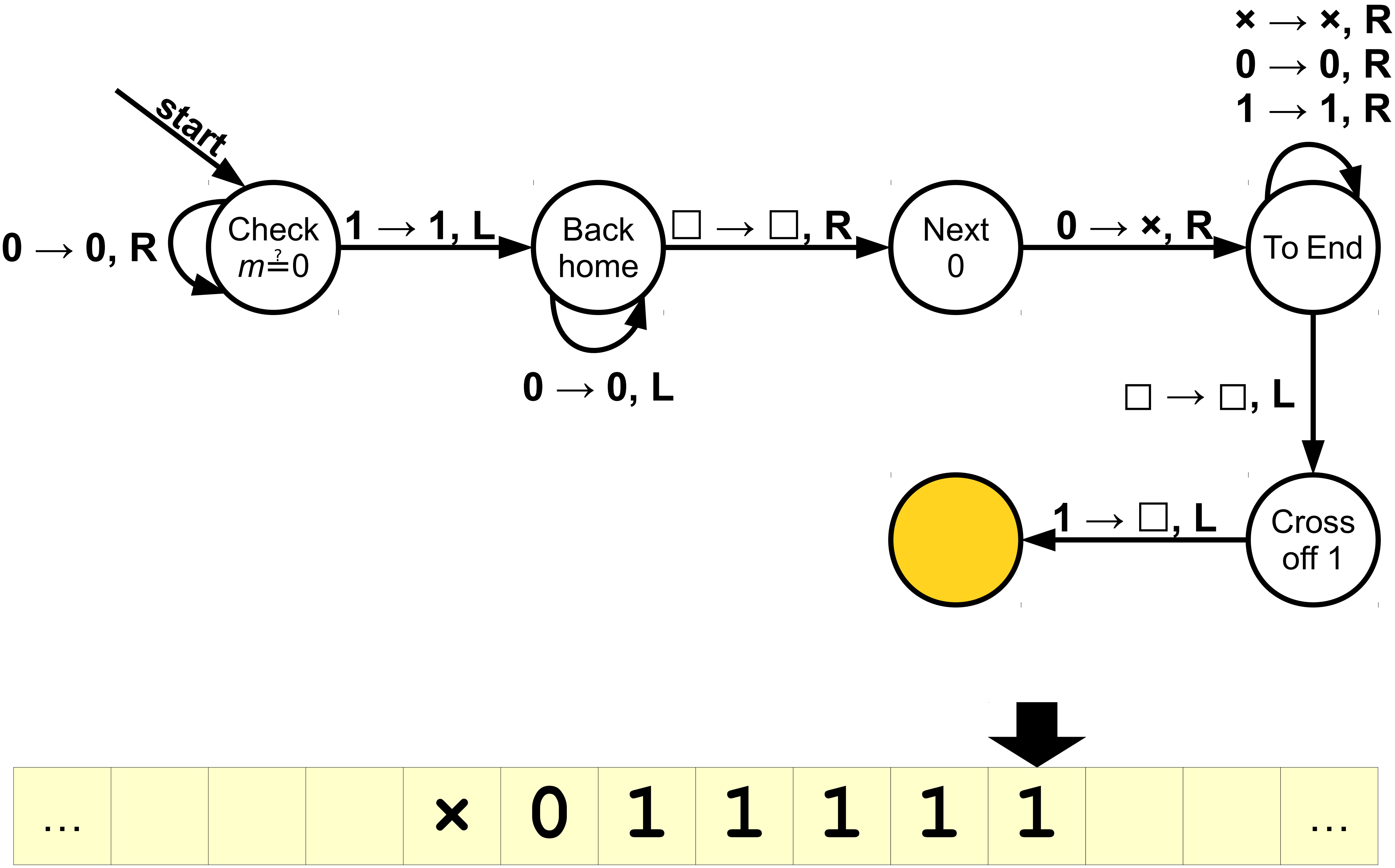
…				×	0	1	1	1	1	1	1		…

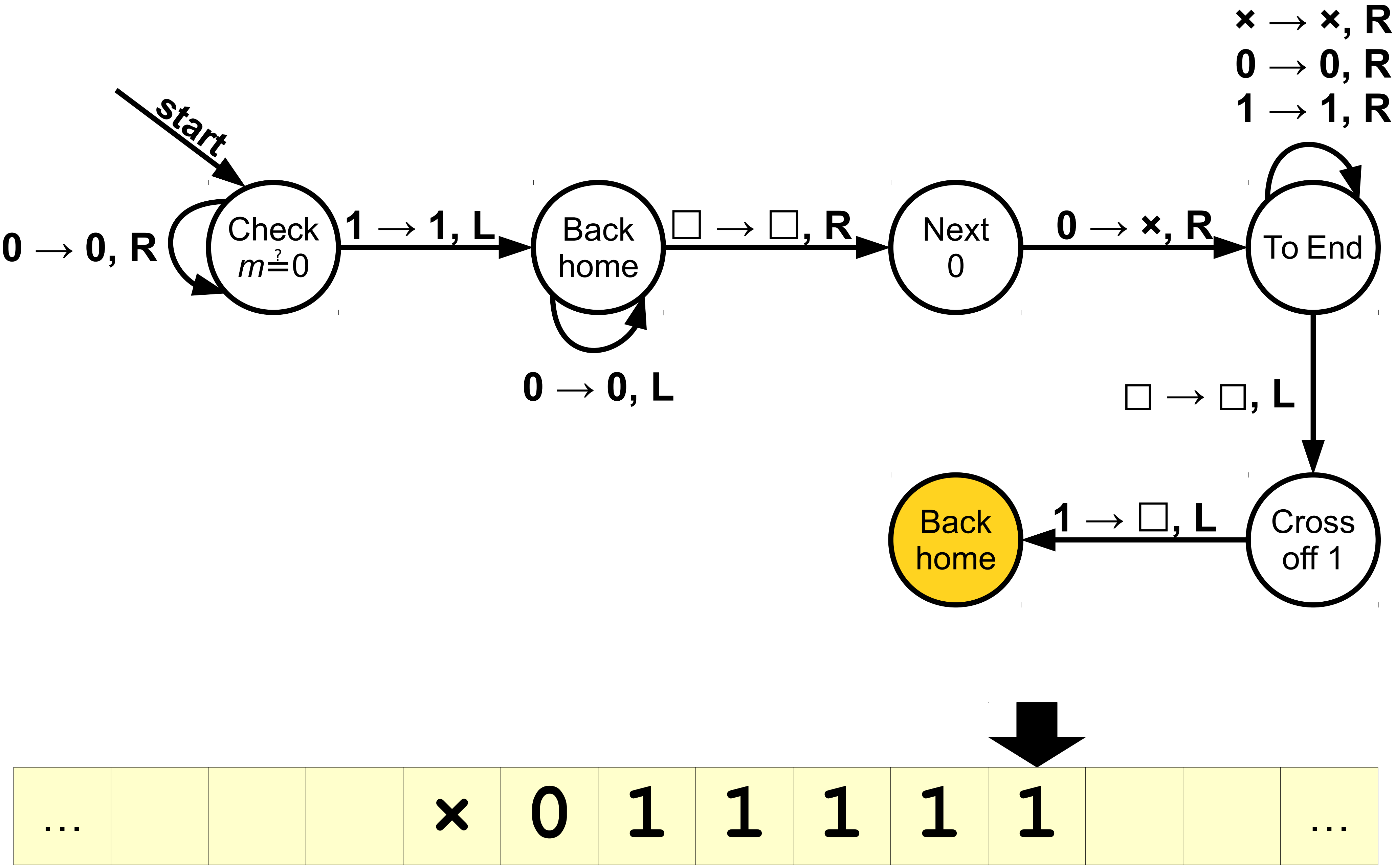


start
0 → 0, R
Check
m ≟ 0
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L

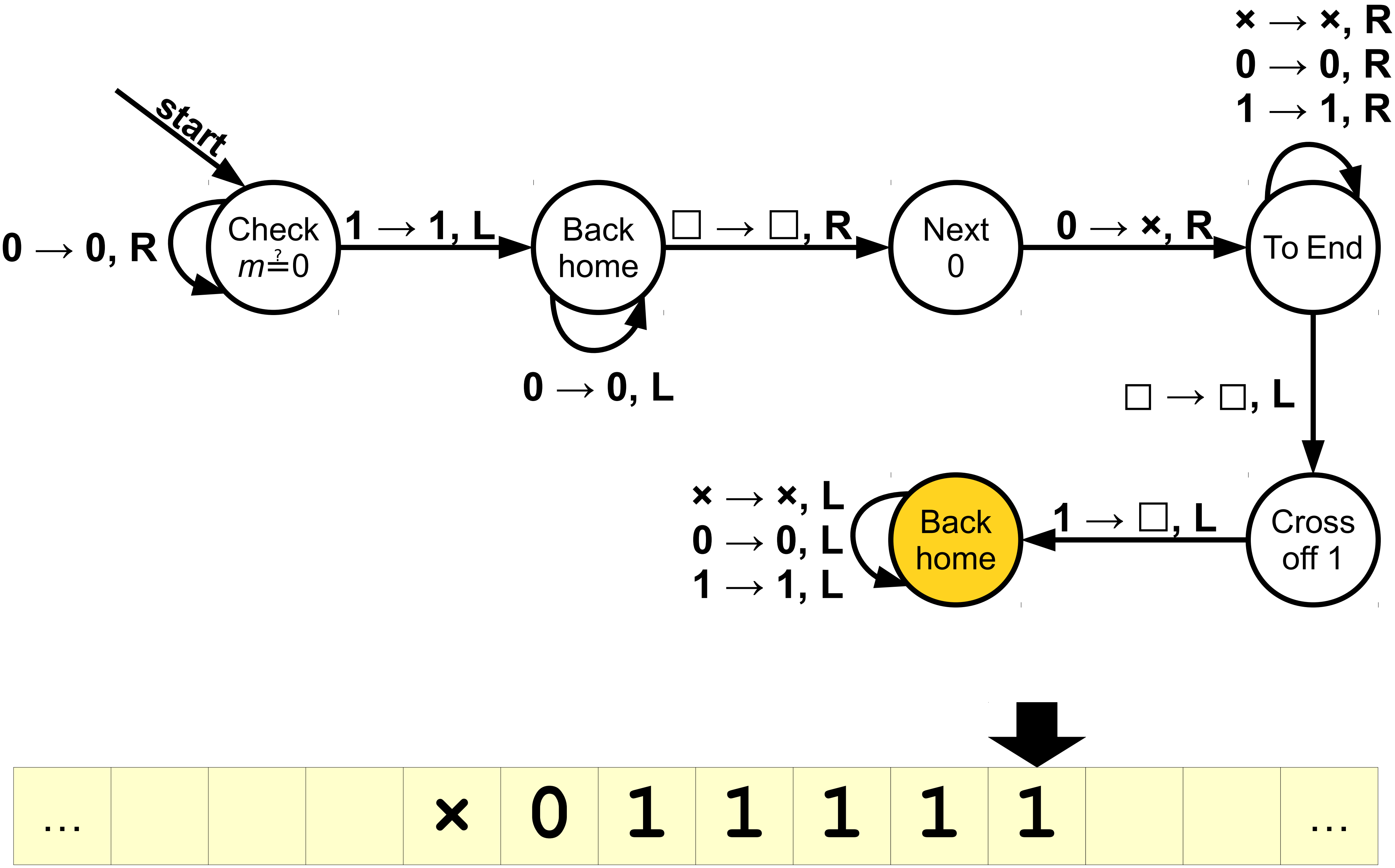


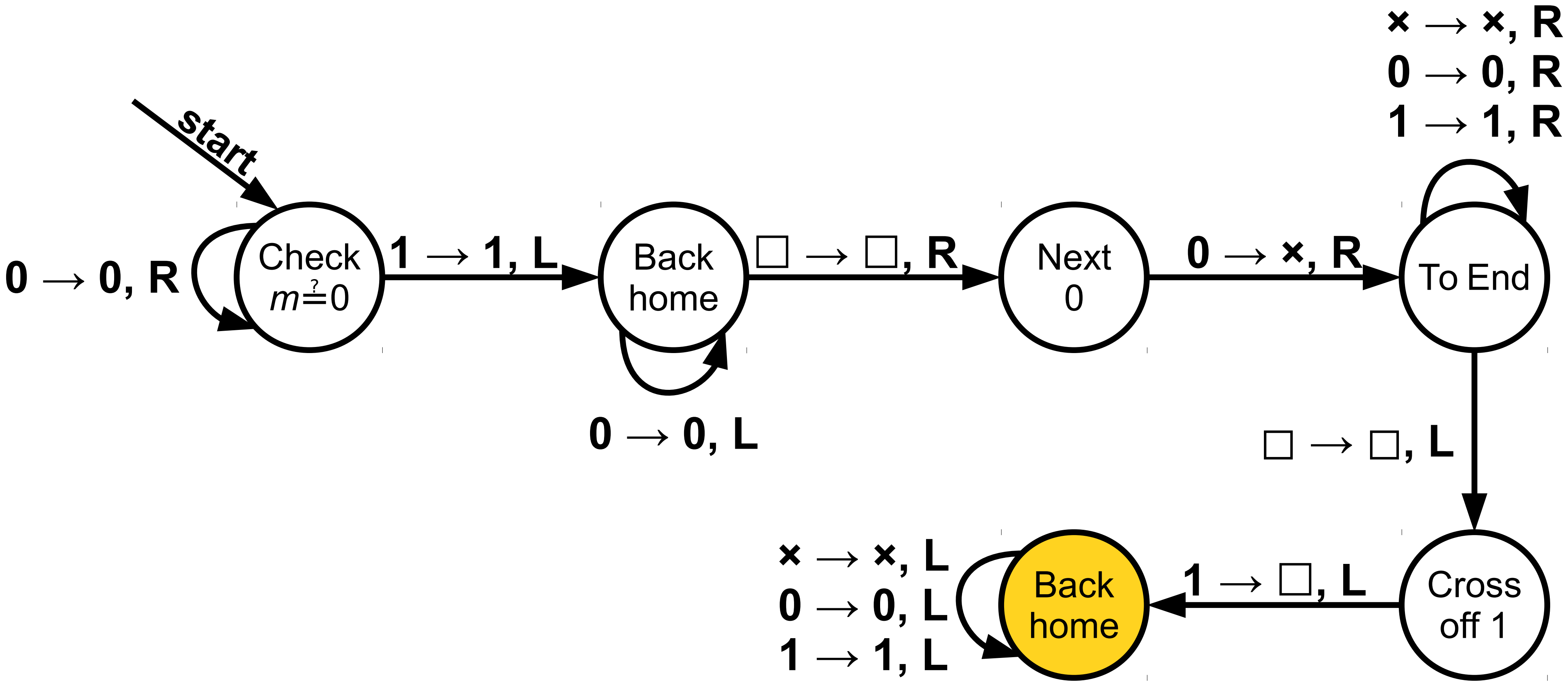
…				×	0	1	1	1	1	1	1		…


start
Check $m\overset{?}{=}0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
…
×
0
1
1
1
1
1
…

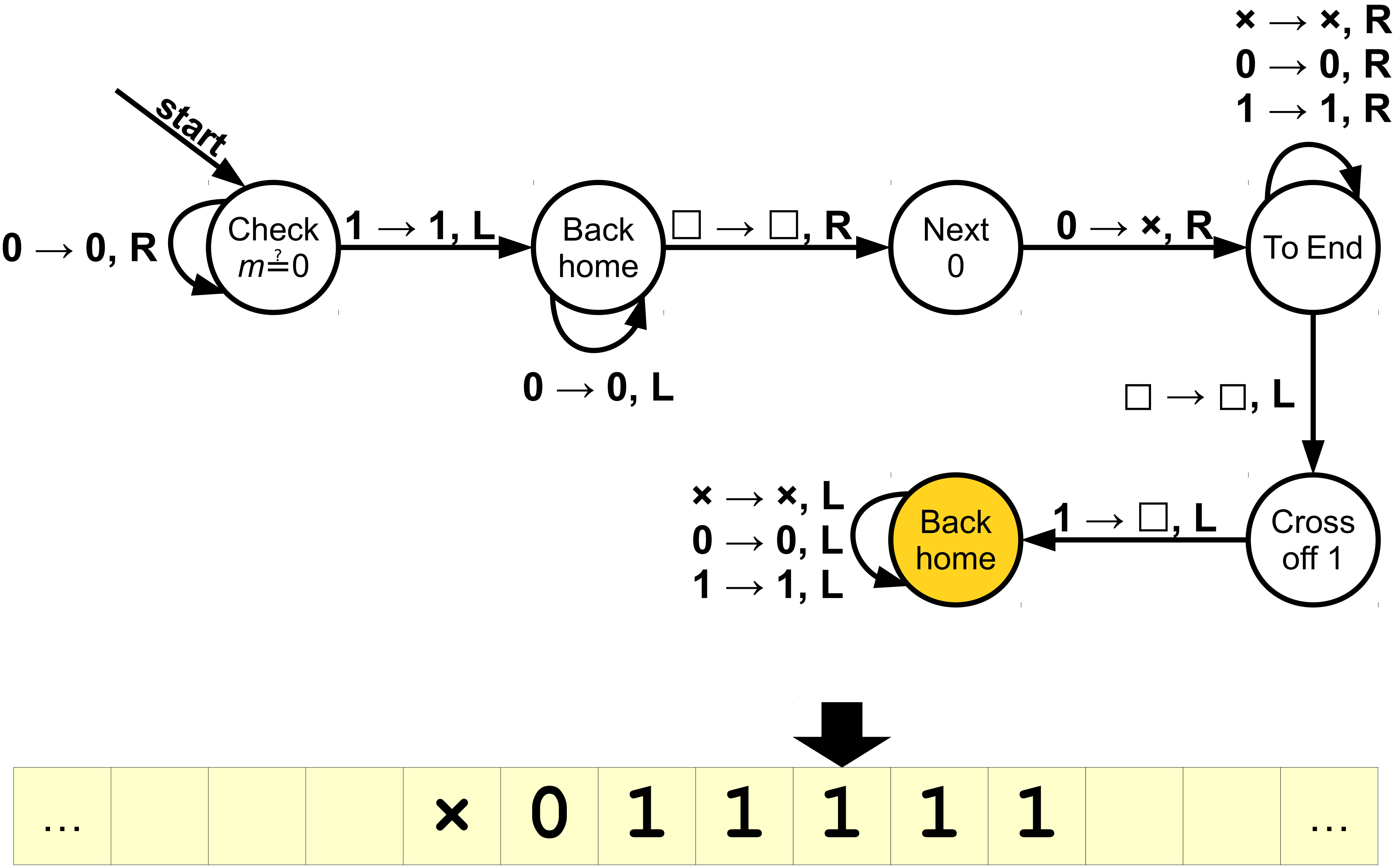

start
Check
$m\overset{?}{=}0$
$0 \rightarrow 0$, R
$1 \rightarrow 1$, L
Back home
$0 \rightarrow 0$, L
$\square \rightarrow \square$, R
Next 0
$0 \rightarrow \times$, R
To End
$\times \rightarrow \times$, R
$0 \rightarrow 0$, R
$1 \rightarrow 1$, R
$\square \rightarrow \square$, L
Cross off 1
$1 \rightarrow \square$, L
Back home

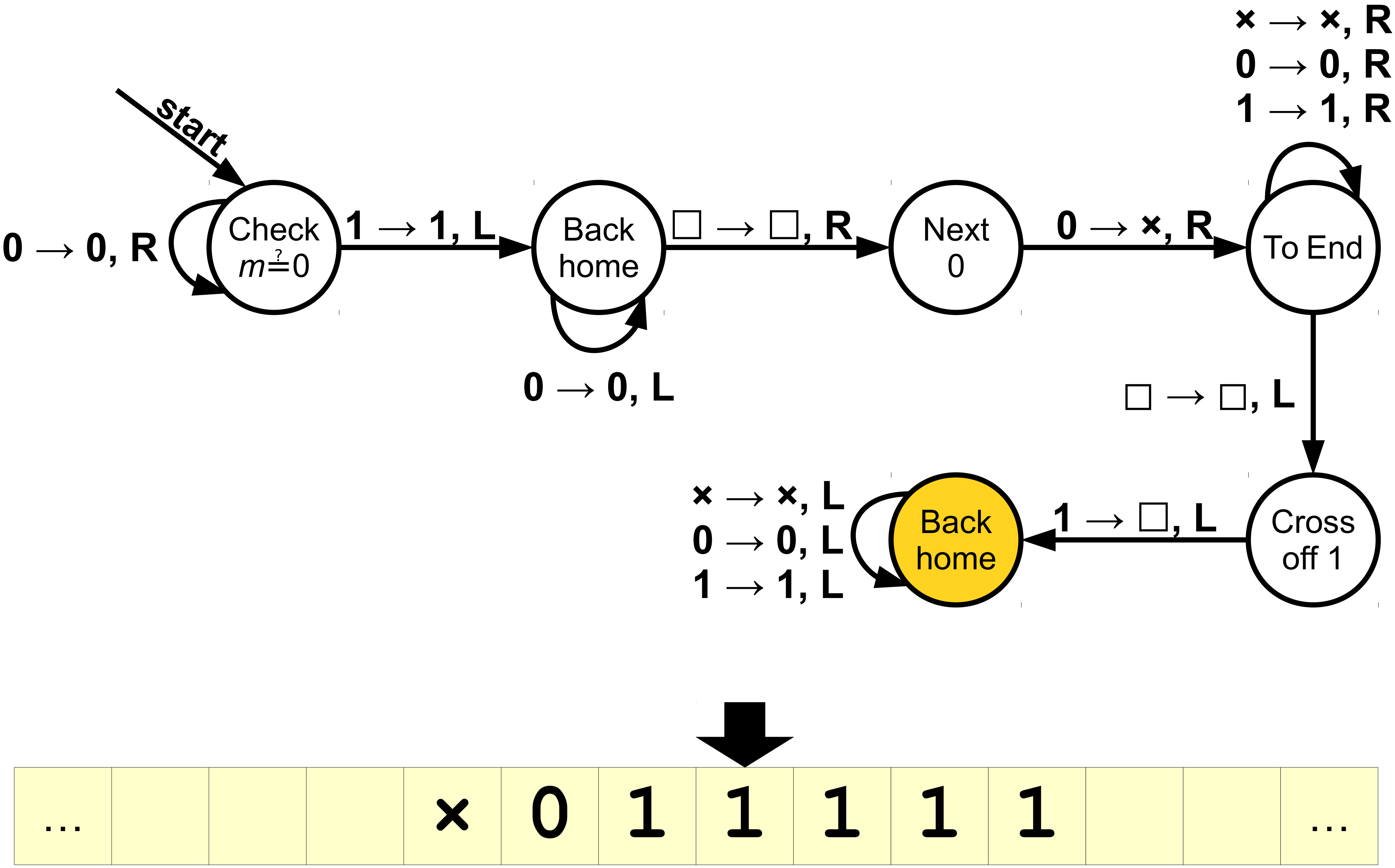
…				×	0	1	1	1	1	1			…

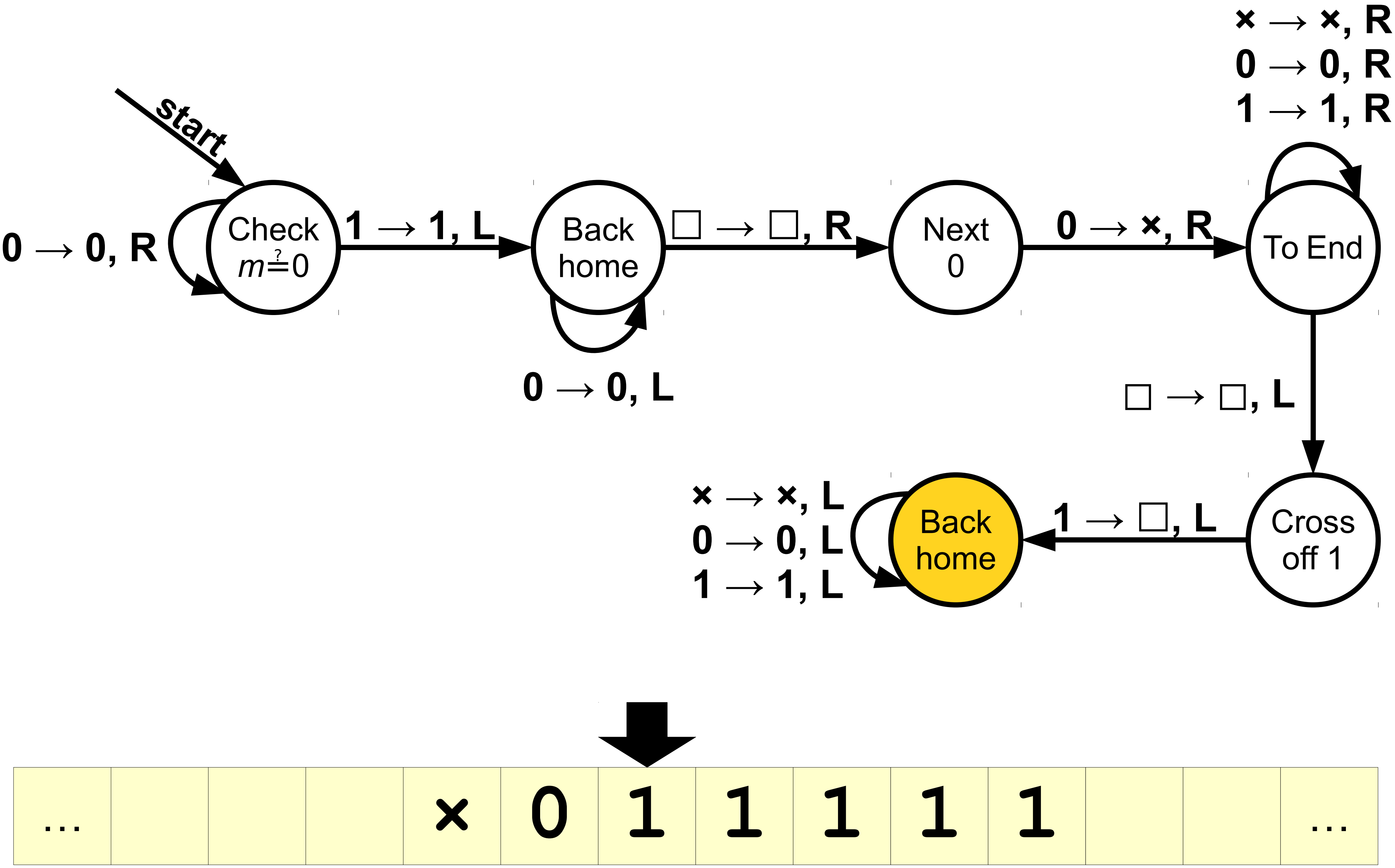

start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
…
×
0
1
1
1
1
1
…

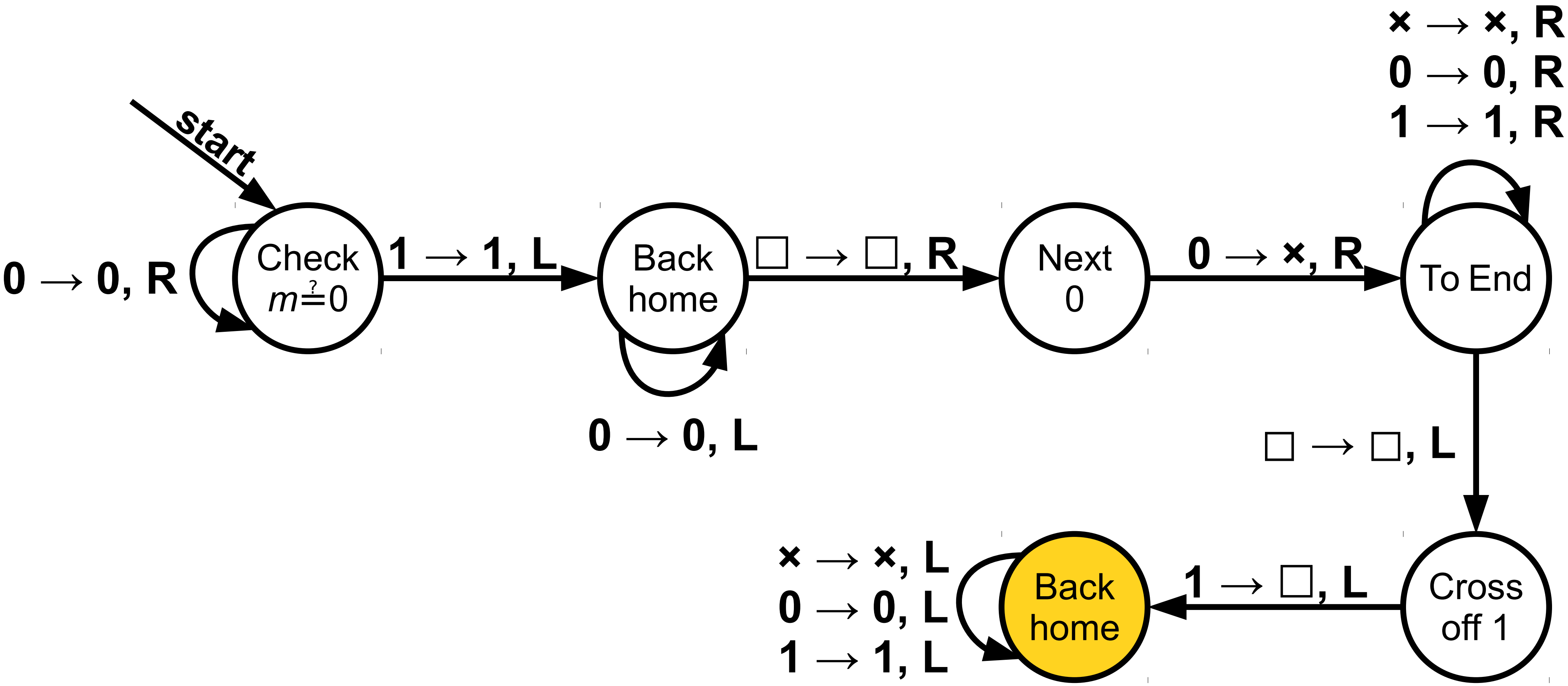

start
Check
$m \stackrel{?}{=} 0$
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L

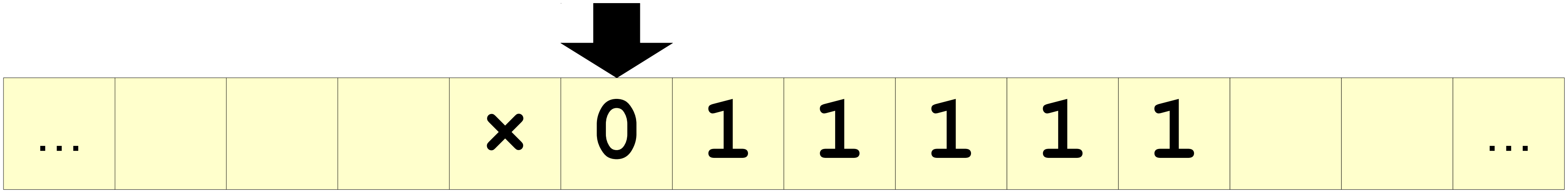
…				×	0	1	1	1	1	1			…


start
Check
$m \stackrel{?}{=} 0$
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
…
×
0
1
1
1
1
1
…

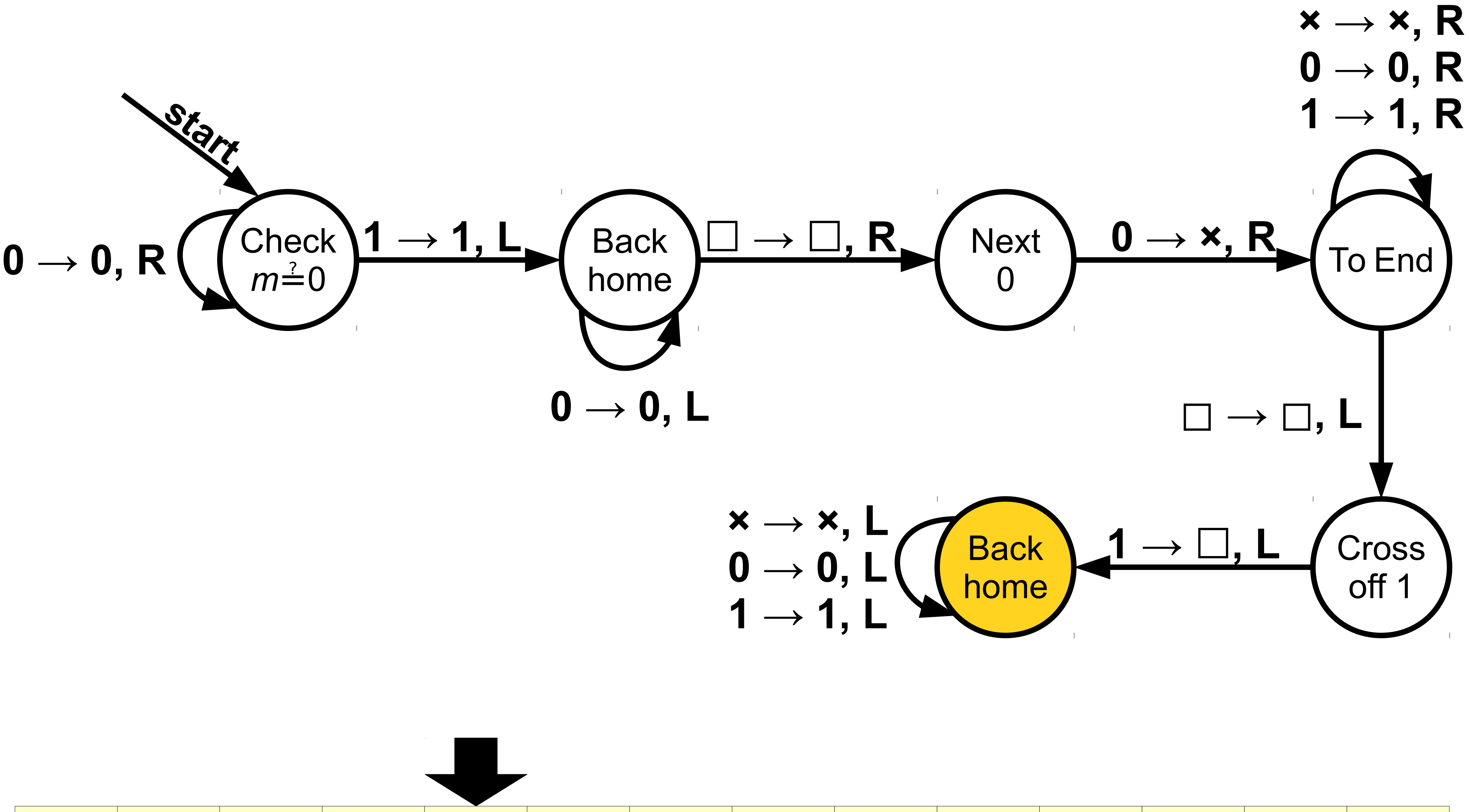

start
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
…
×
0
1
1
1
1
1
…


start
Check
$m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
…
×
0
1
1
1
1
1
…

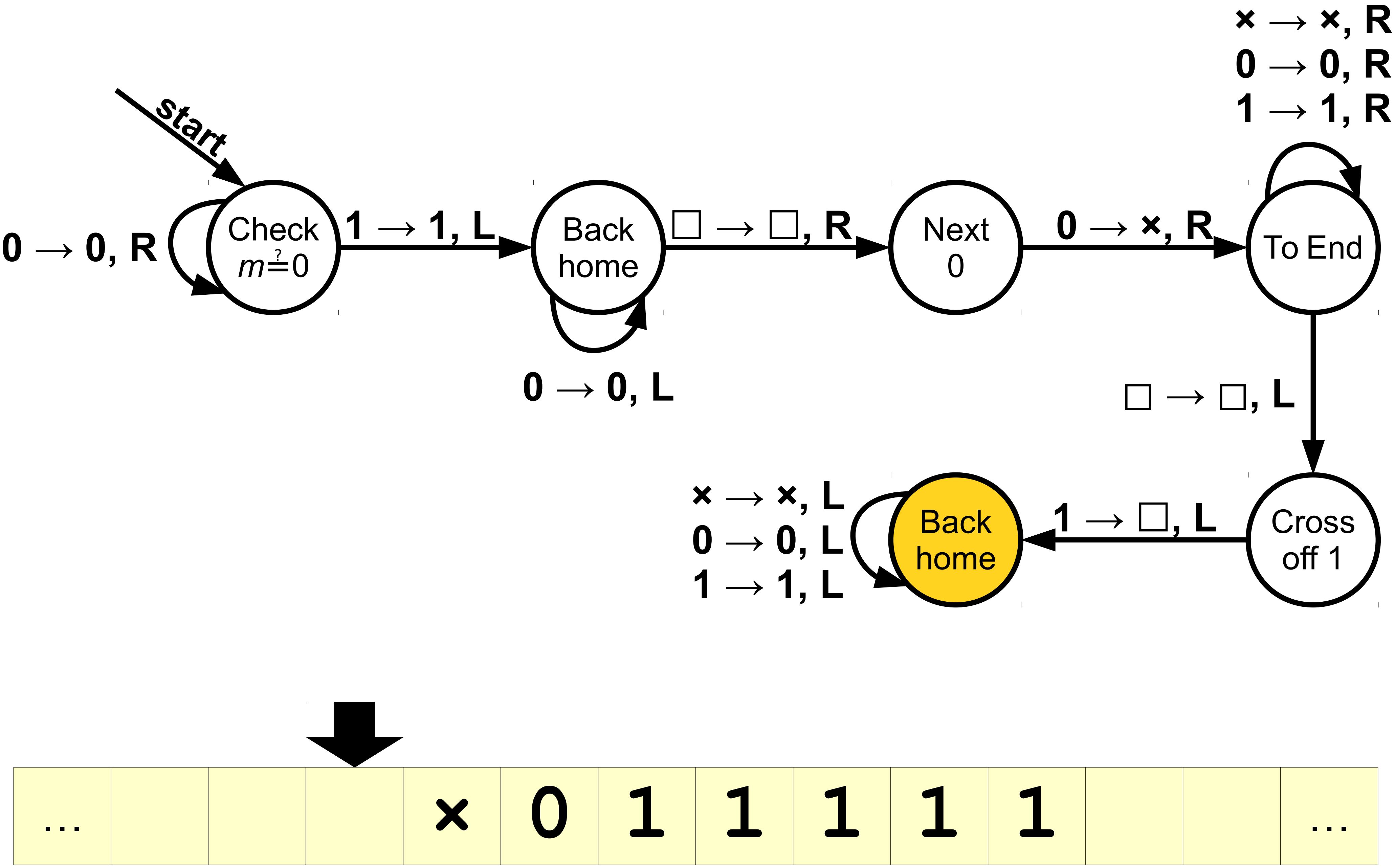

start
Check
$m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L

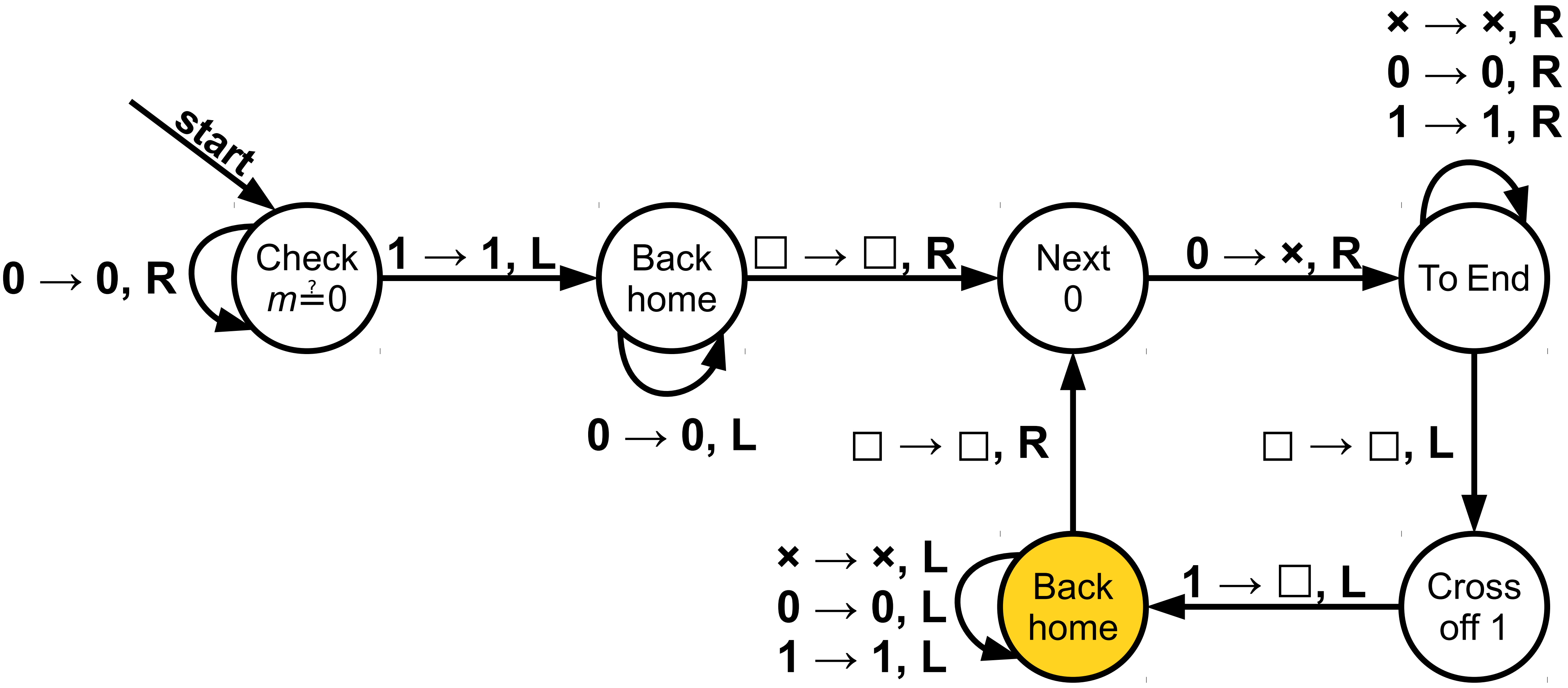


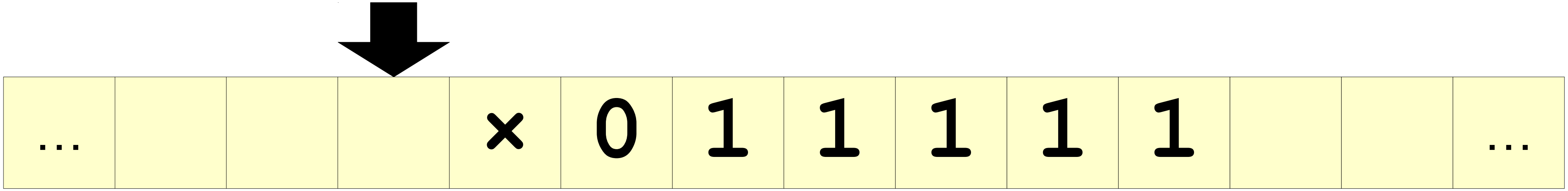
…				×	0	1	1	1	1	1			…

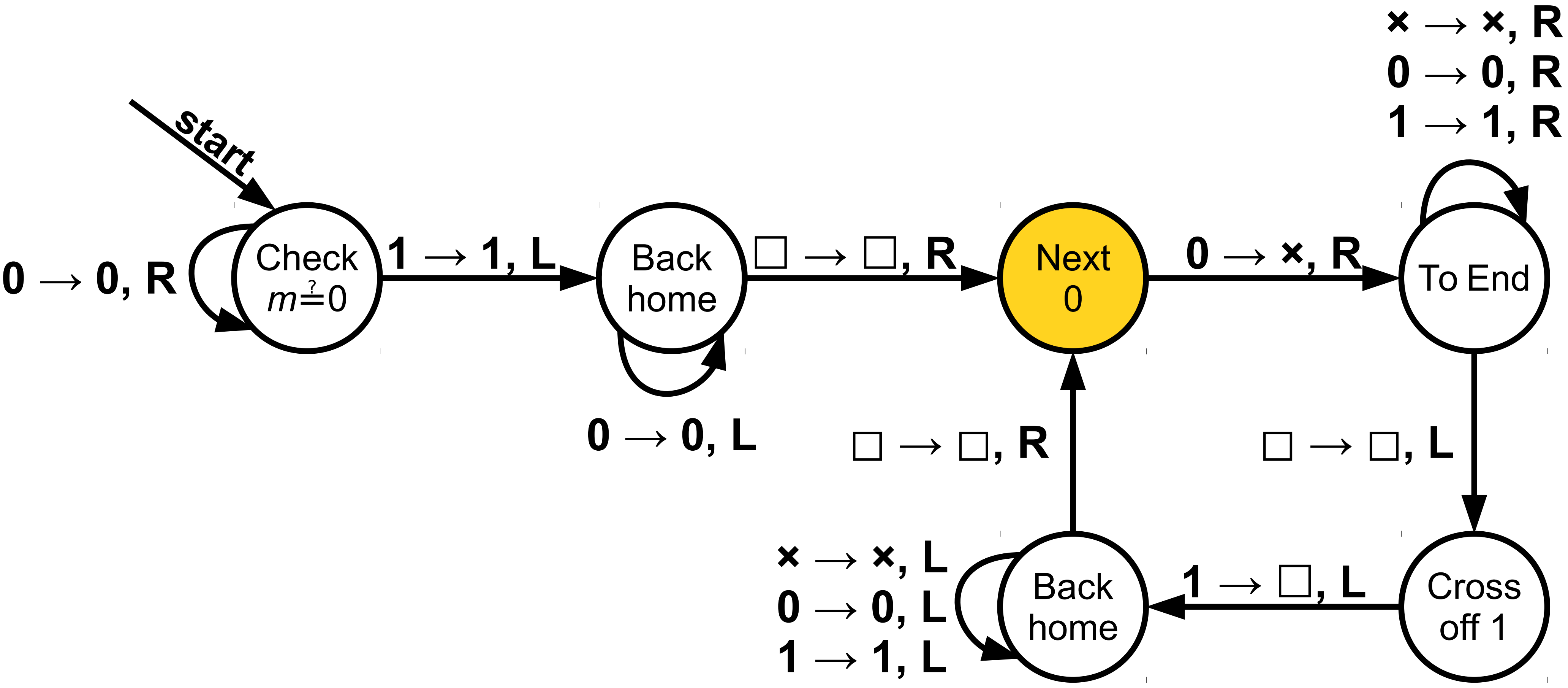

start
Check
$m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L

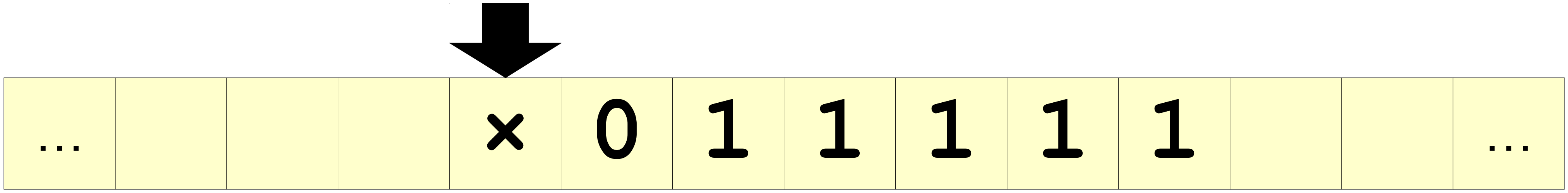
…				×	0	1	1	1	1	1			…


start
0 → 0, R
Check $m \overset{?}{=} 0$
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
…
×
0
1
1
1
1
1
…

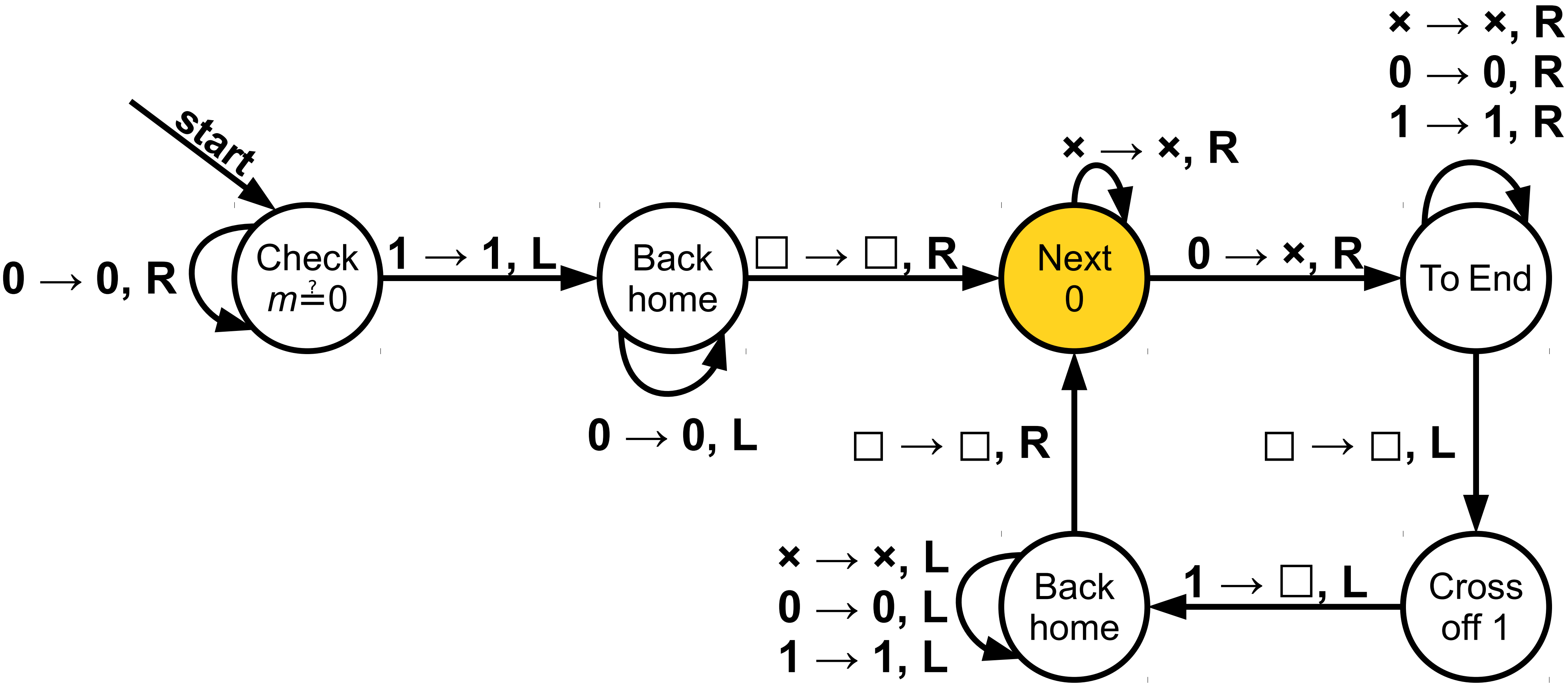

start
0 → 0, R
Check
m ≟ 0
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R


…
×
0
1
1
1
1
1
…

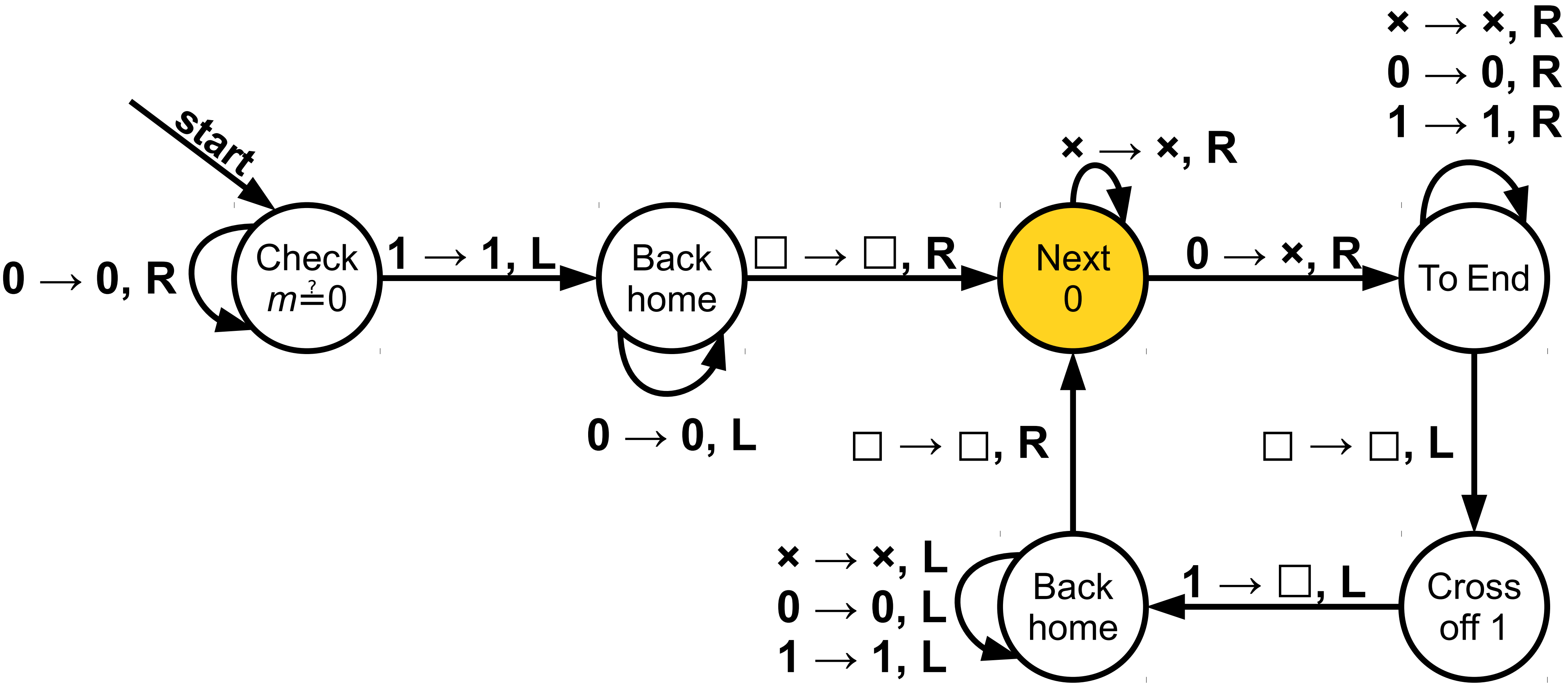

start
0 → 0, R
Check
m≟0
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R

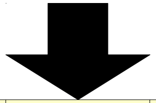


…				×	0	1	1	1	1	1			…

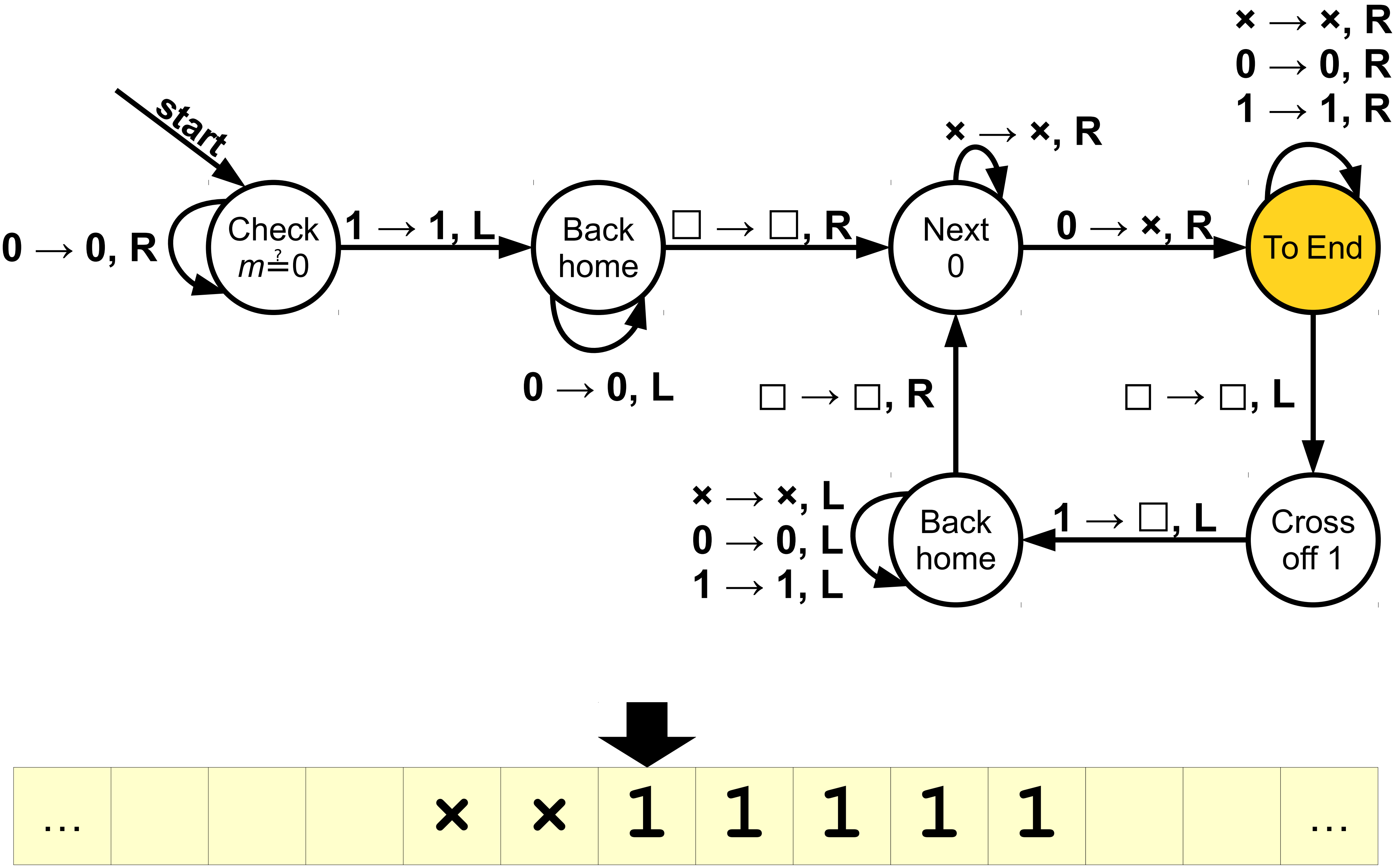

start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back home
0 → 0, L
□ → □, R
× → ×, R
Next 0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R

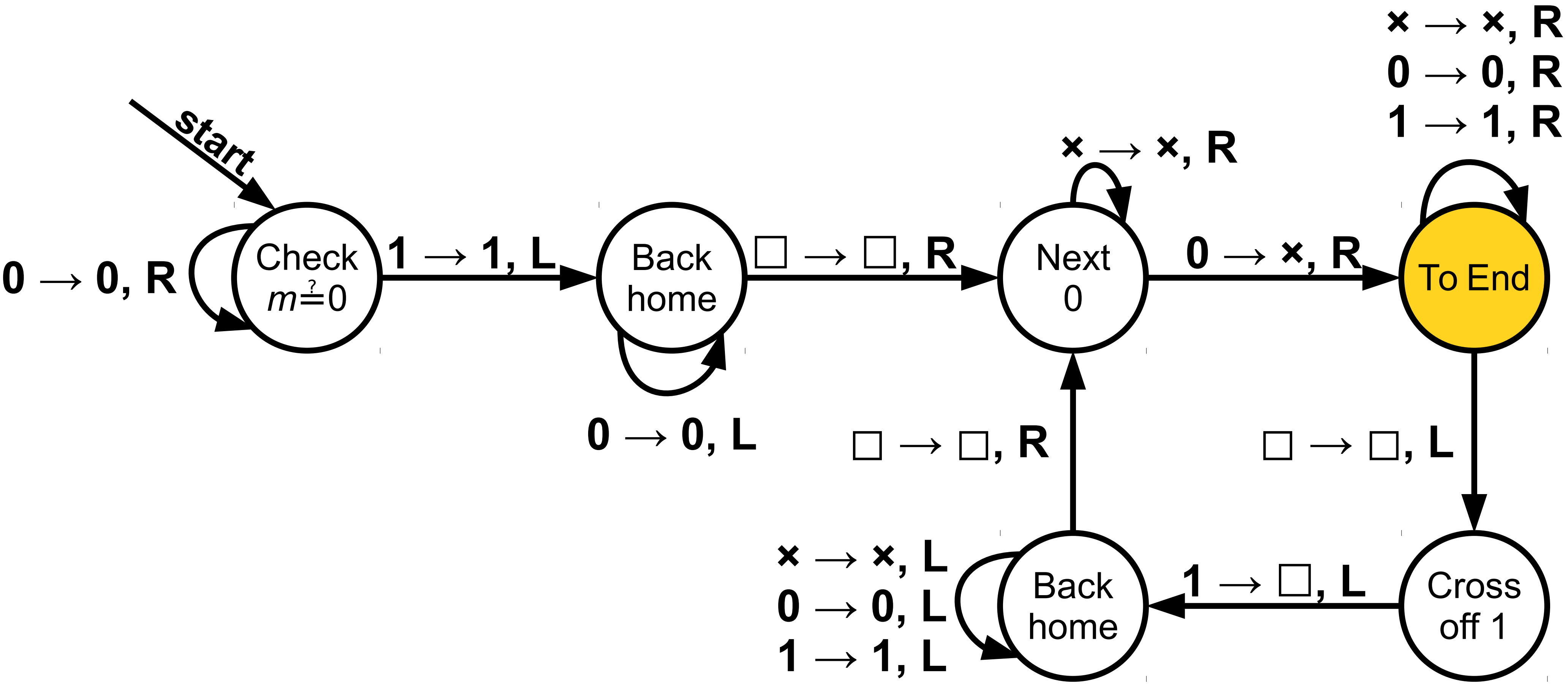
…				×	0	1	1	1	1	1			…

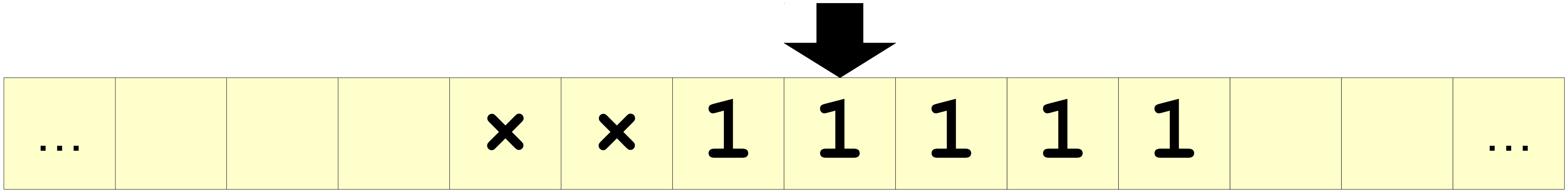

start
0 → 0, R
Check
m ≟ 0
1 → 1, L
Back
home
0 → 0, L
□ → □, R
× → ×, R
Next
0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R



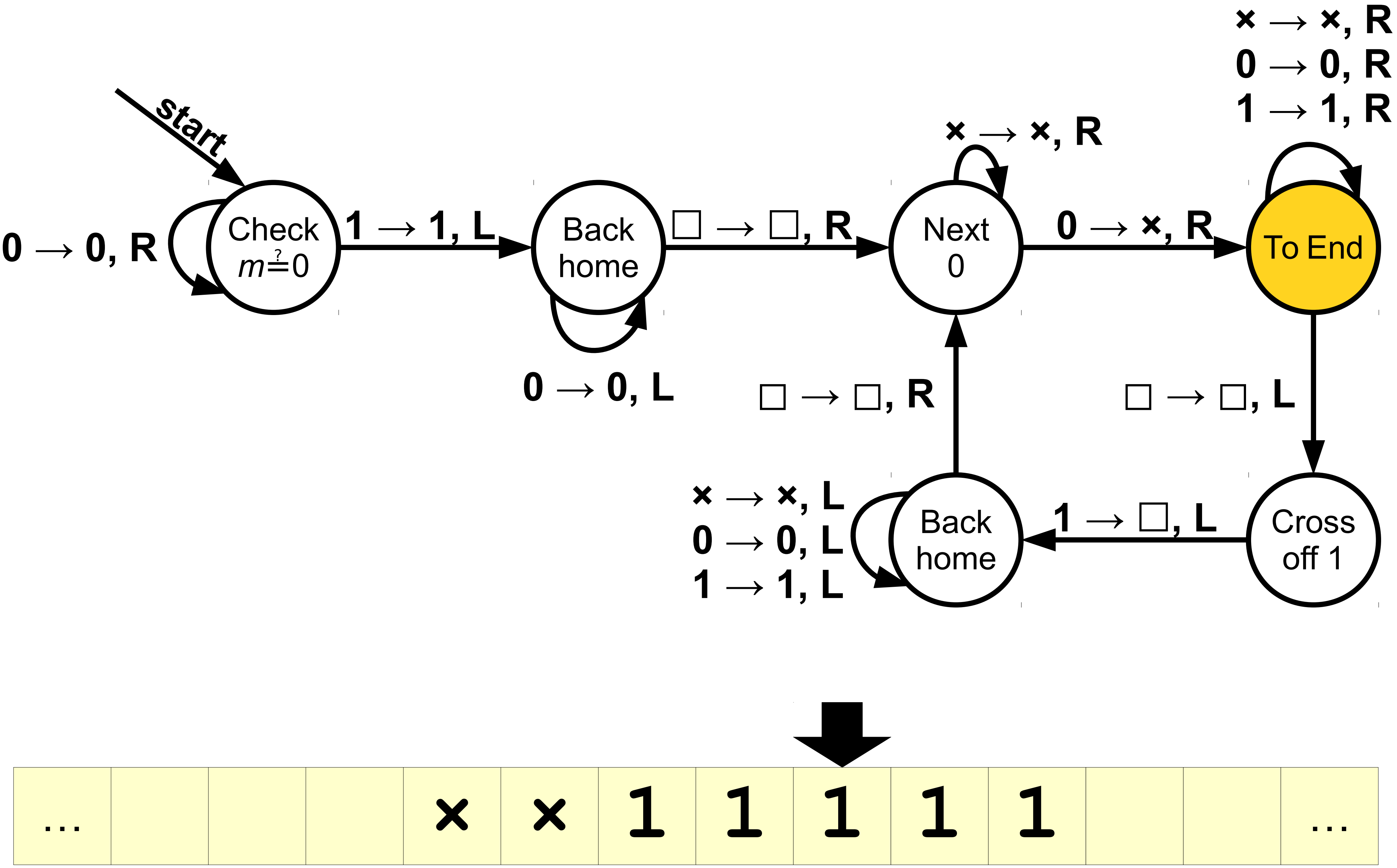
…				×	0	1	1	1	1	1			…

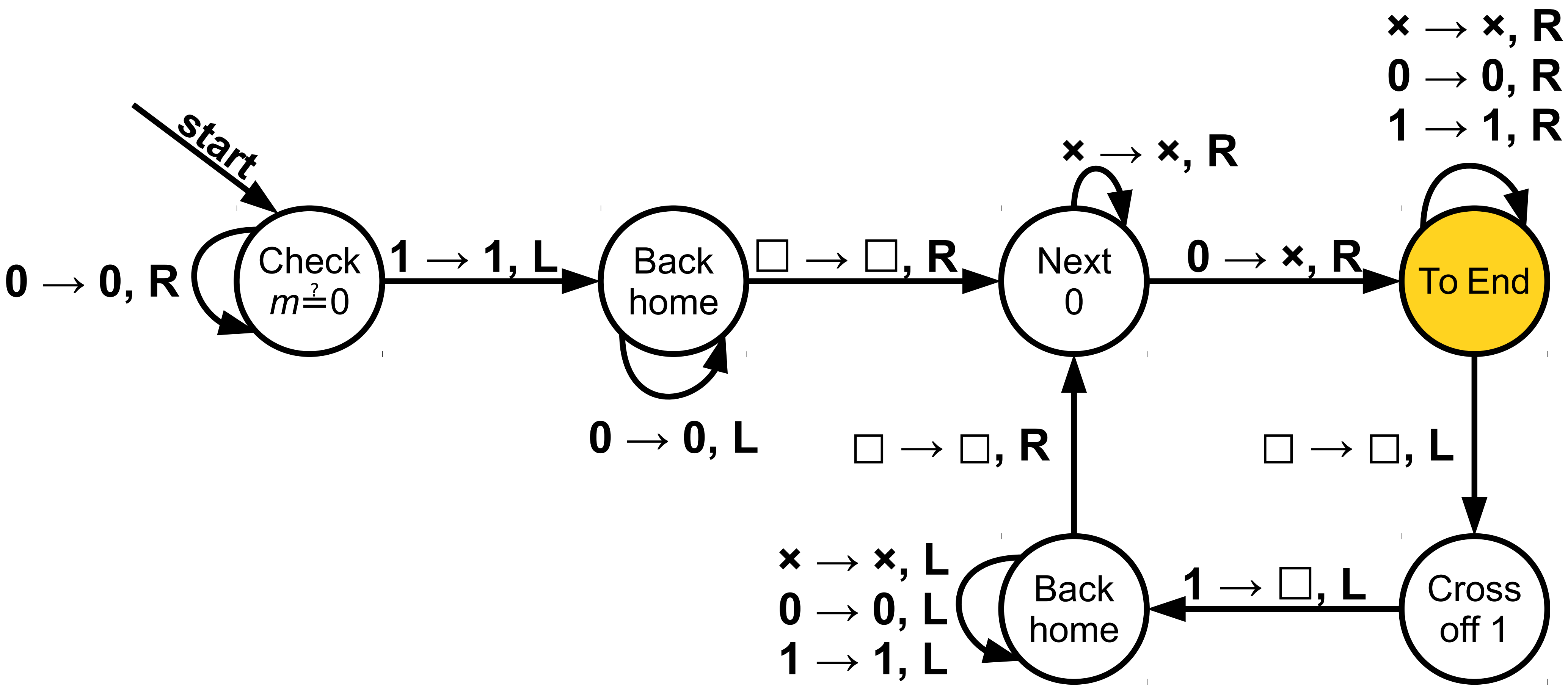

start
0 → 0, R
Check $m \overset{?}{=} 0$
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
1
1
1
1
1
…


start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
0 → 0, L
□ → □, R
× → ×, R
Next
0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, L
□ → □, R
Cross
off 1
1 → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home

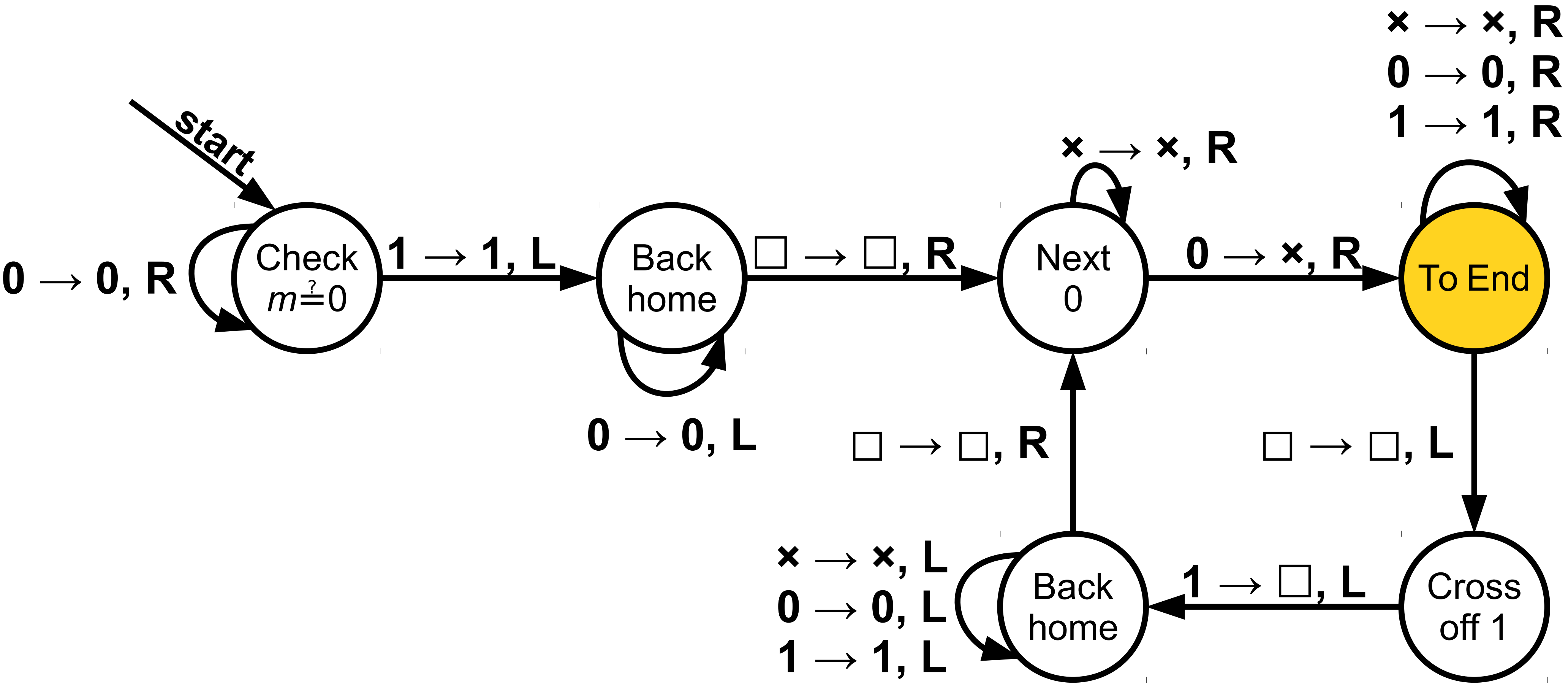


…				×	×	1	1	1	1	1			…

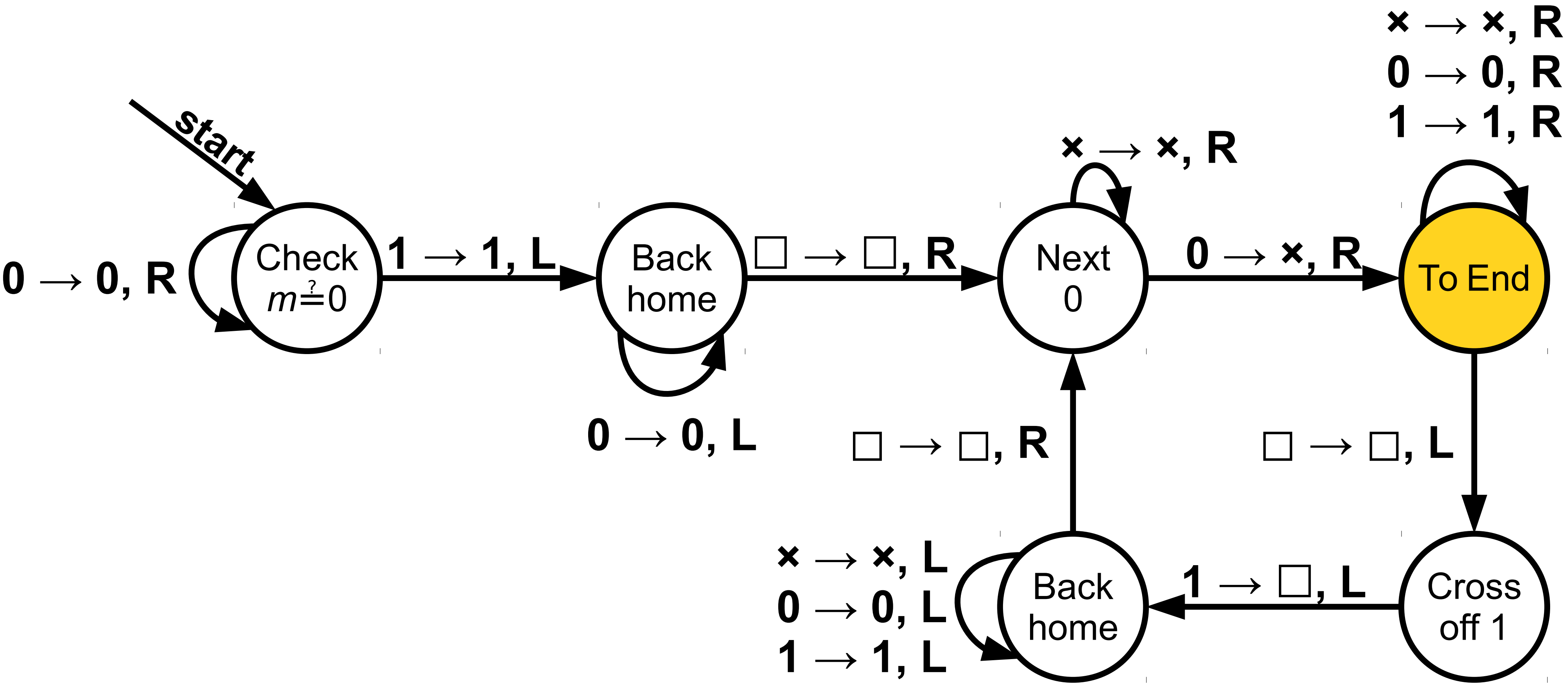

start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
1
1
1
1
1
…


start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R

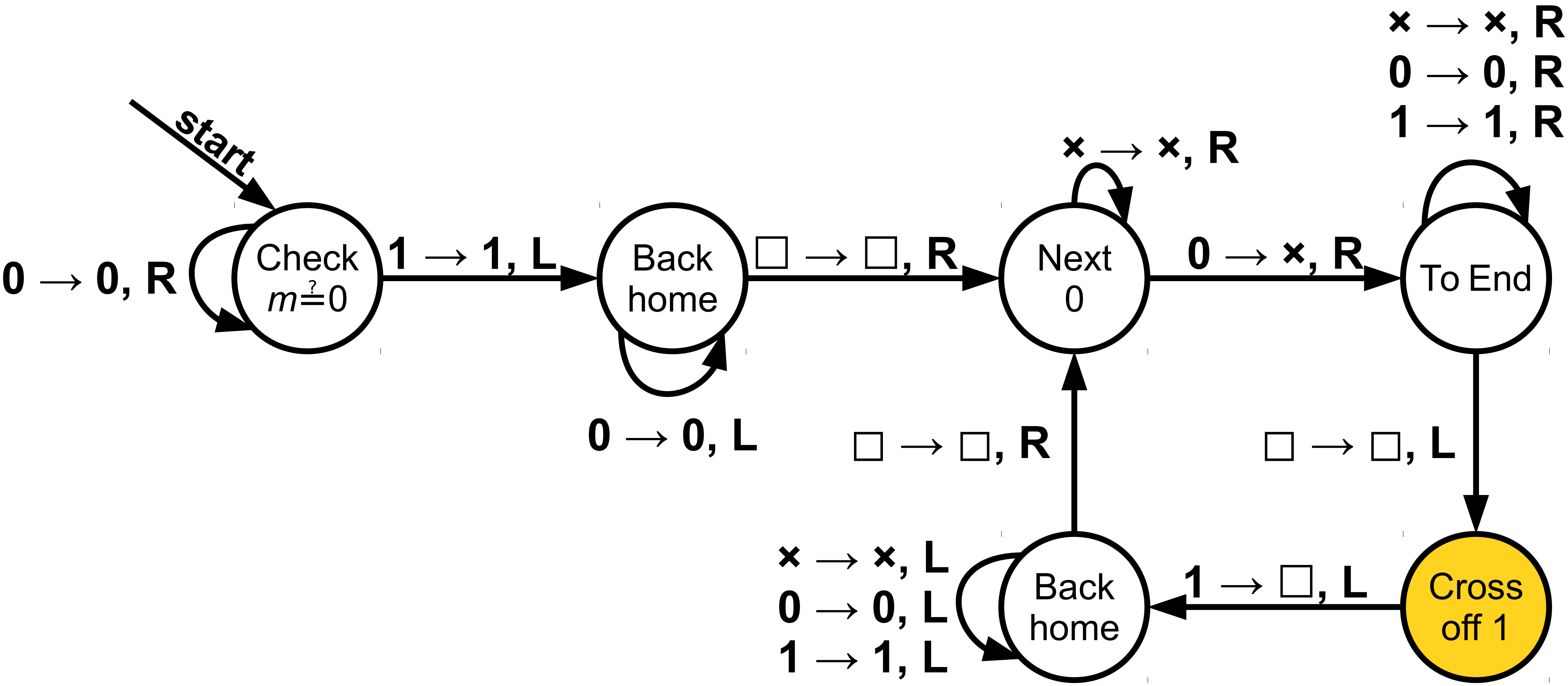
…				×	×	1	1	1	1	1			…


start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
0 → 0, L
□ → □, R
× → ×, R
Next
0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, L
□ → □, R
Cross
off 1
1 → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home

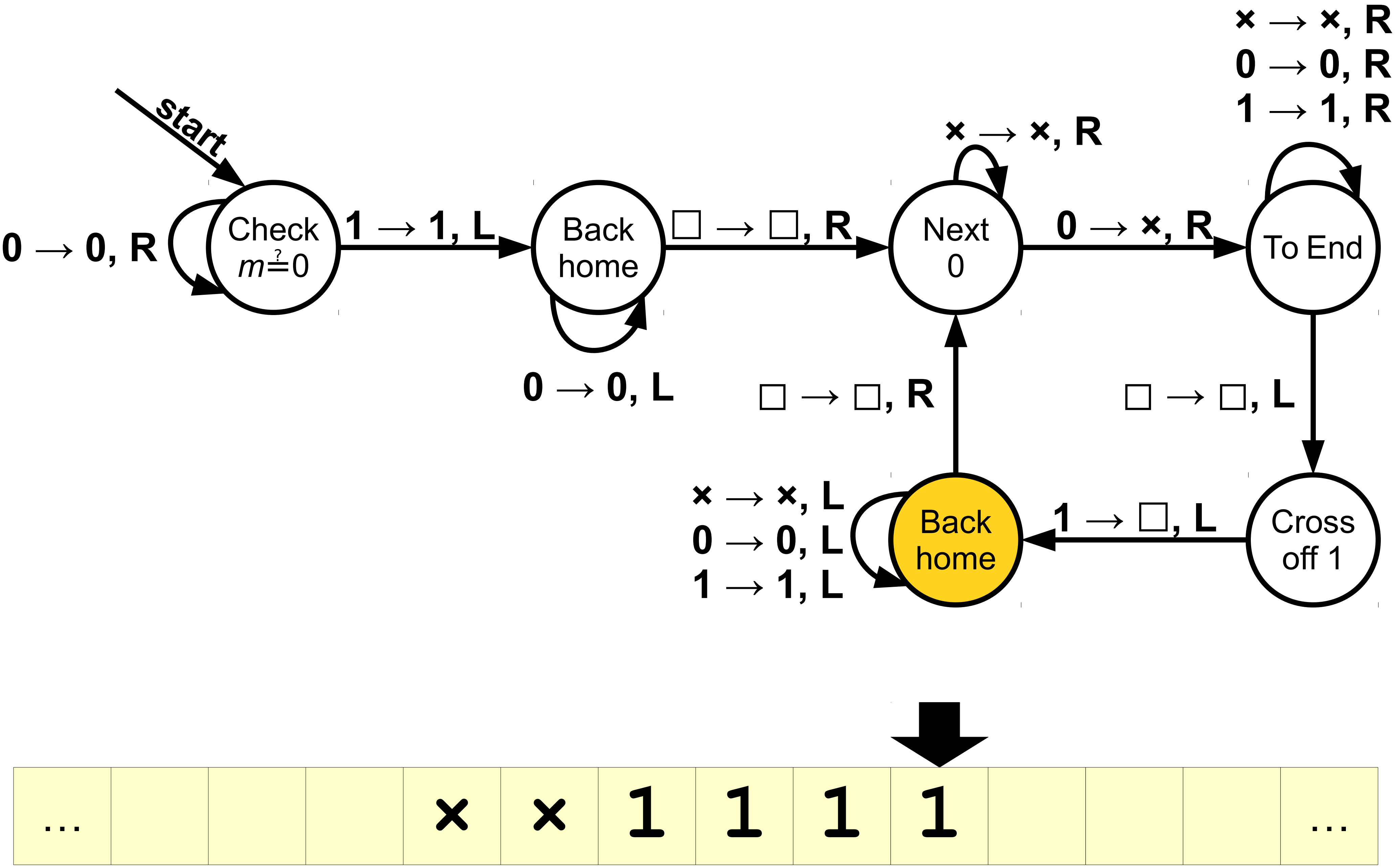
…				×	×	1	1	1	1	1			…

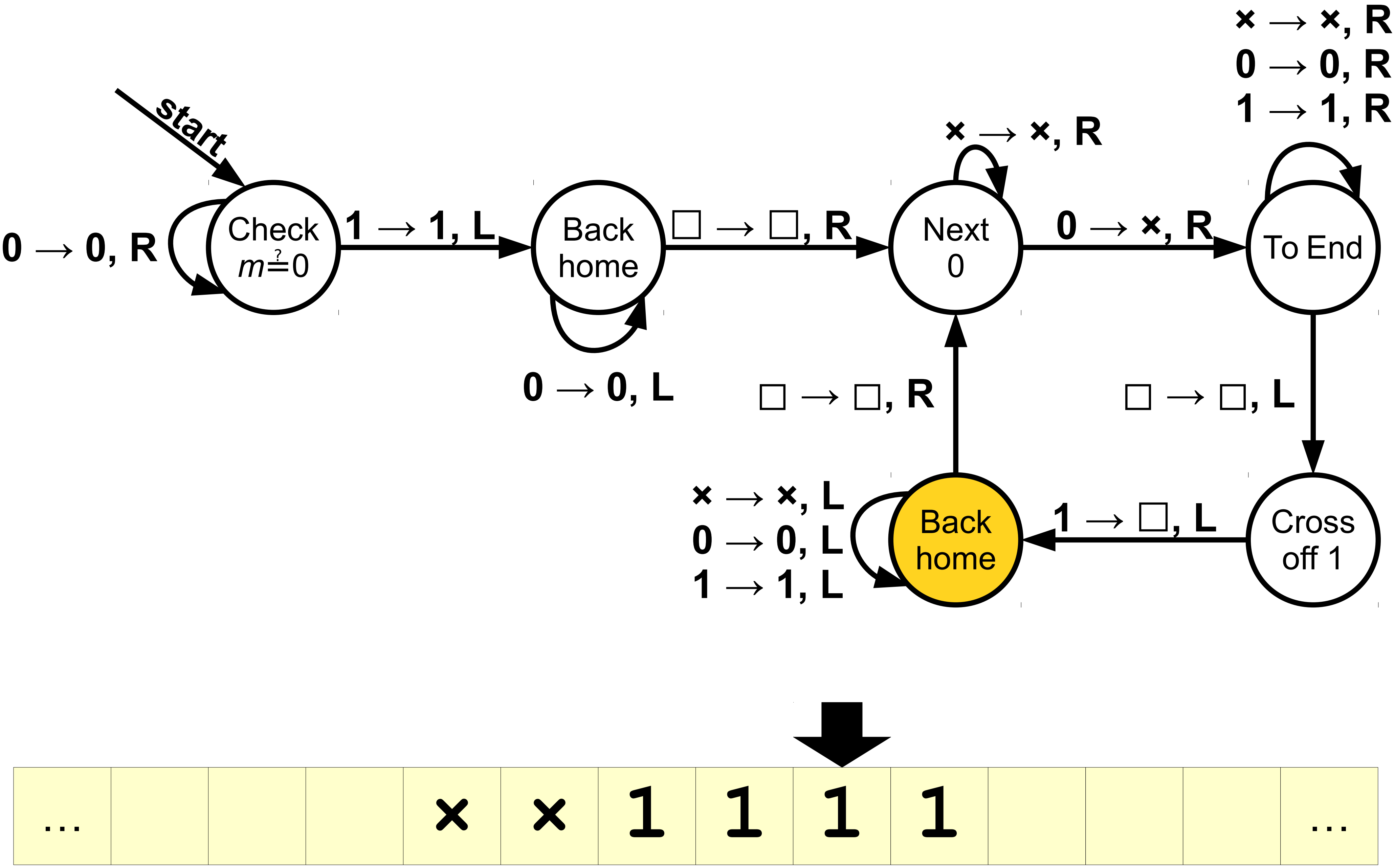

start
Check
m≟0
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
× → ×, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R

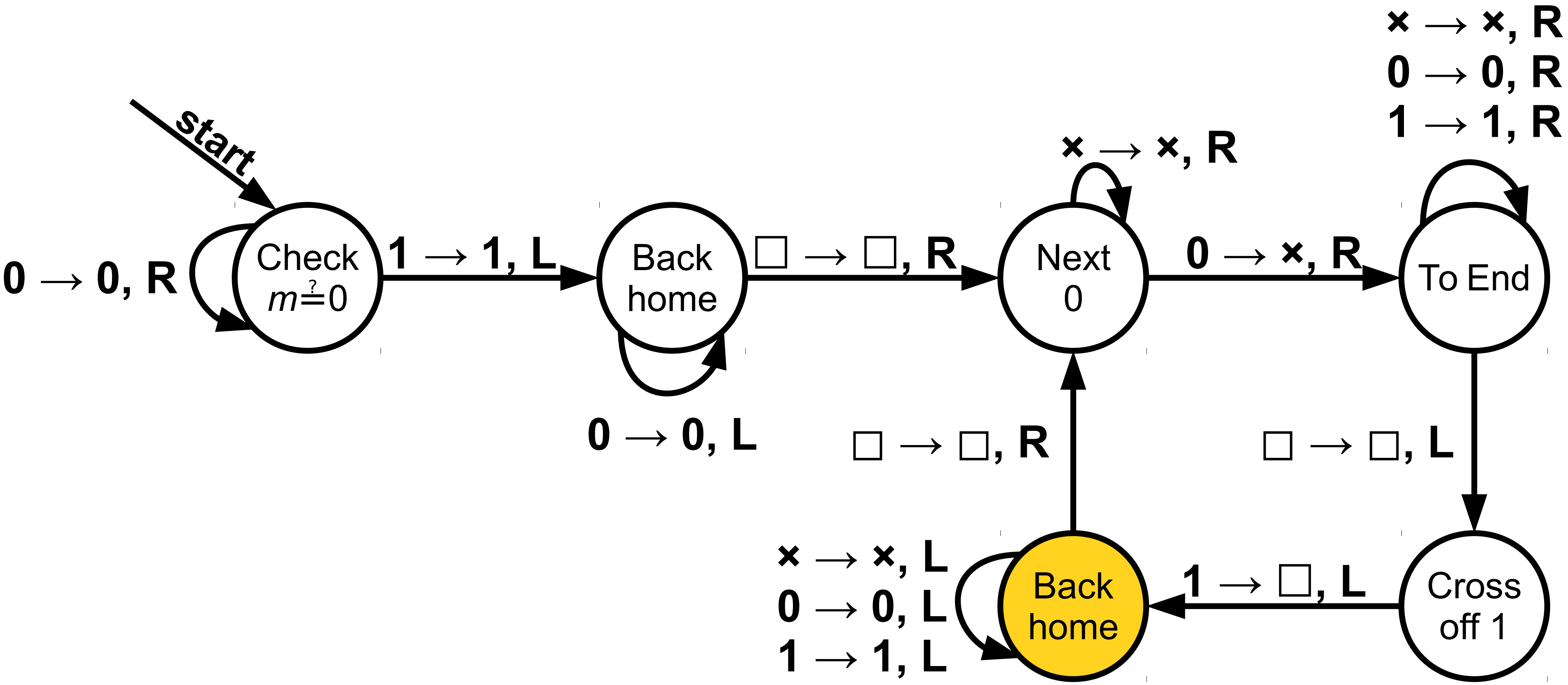
…				×	×	1	1	1	1	1			…

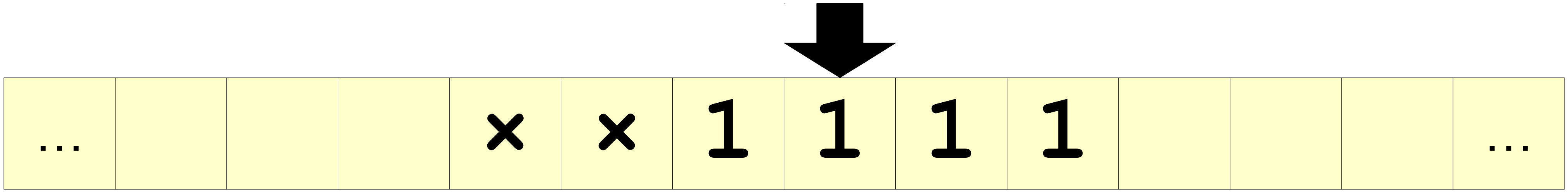

start
Check
$m \stackrel{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R

…				×	×	1	1	1	1	1			…

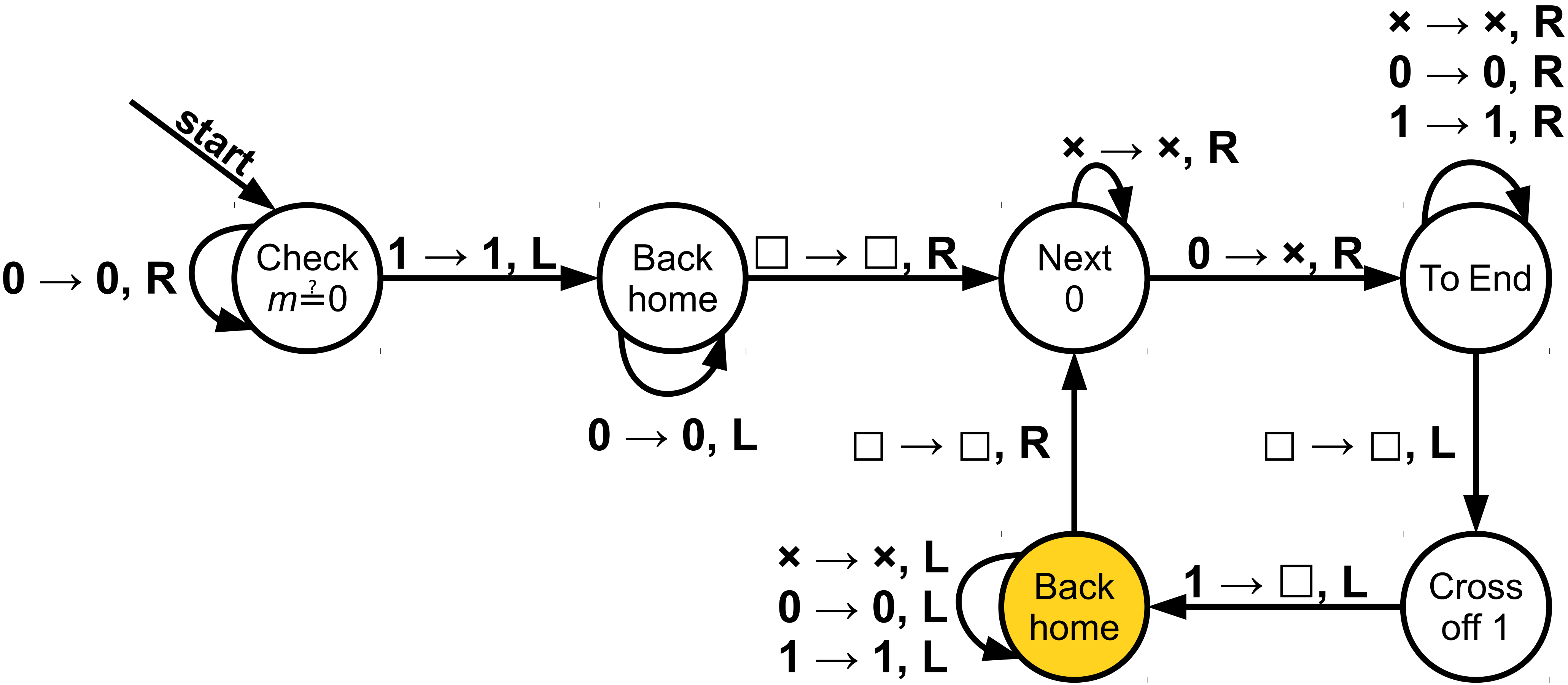

start
Check
$m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
× → ×, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
1
1
1
1
…


start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
1
1
1
1
…

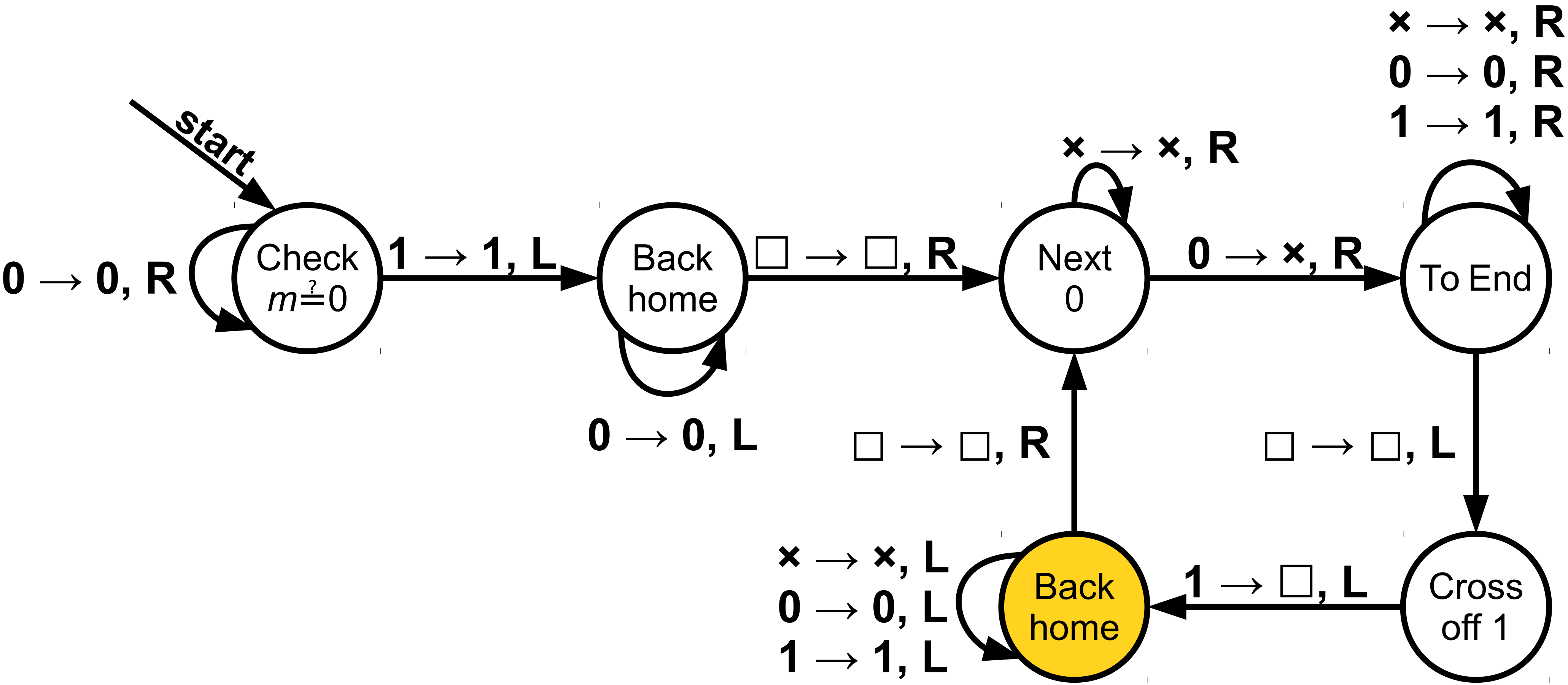

start
Check
$m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
× → ×, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R



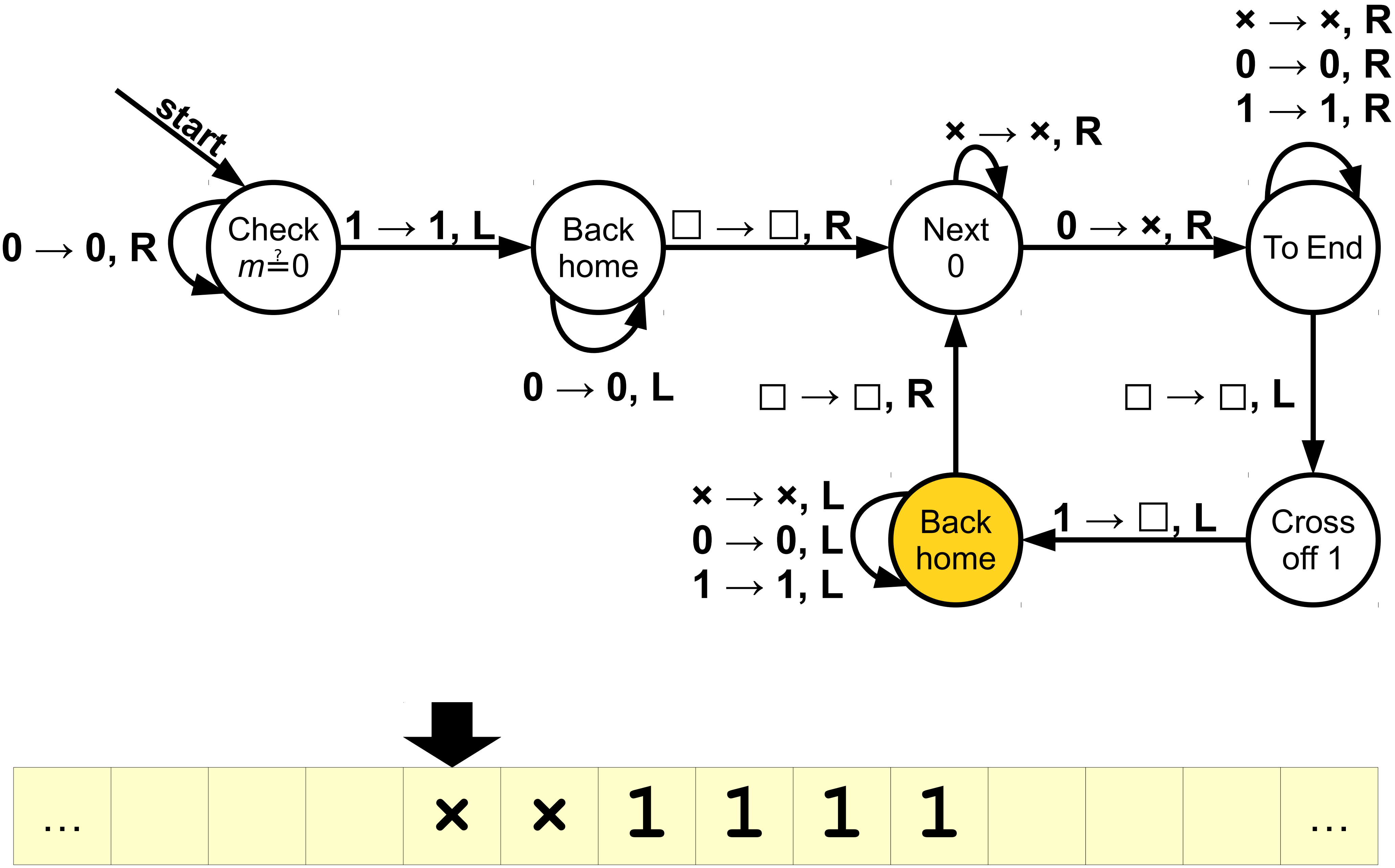
…				×	×	1	1	1	1				…

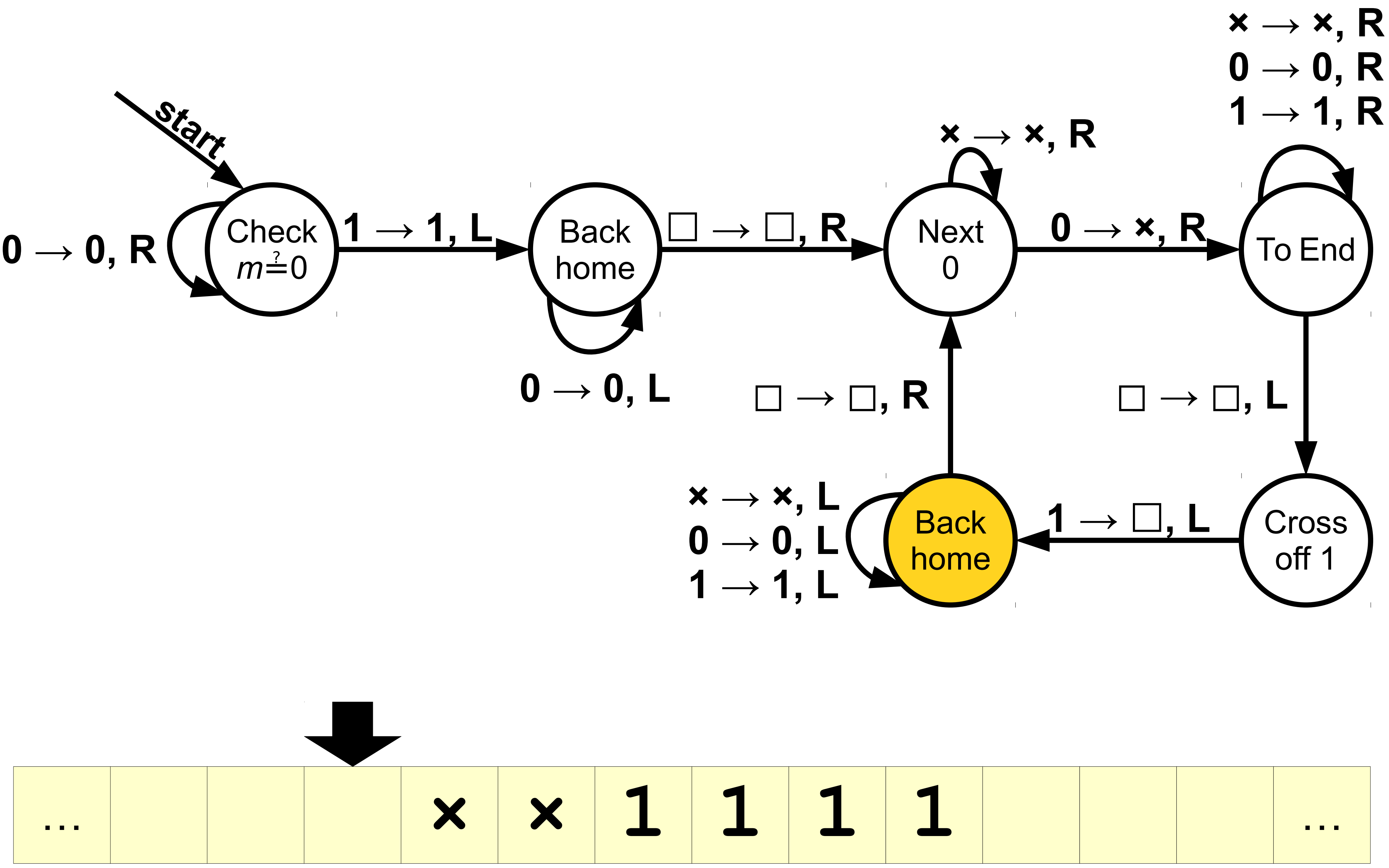

start
0 → 0, R
Check
m ≟ 0
1 → 1, L
Back
home
0 → 0, L
□ → □, R
× → ×, R
Next
0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, L
□ → □, R
Cross
off 1
1 → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home

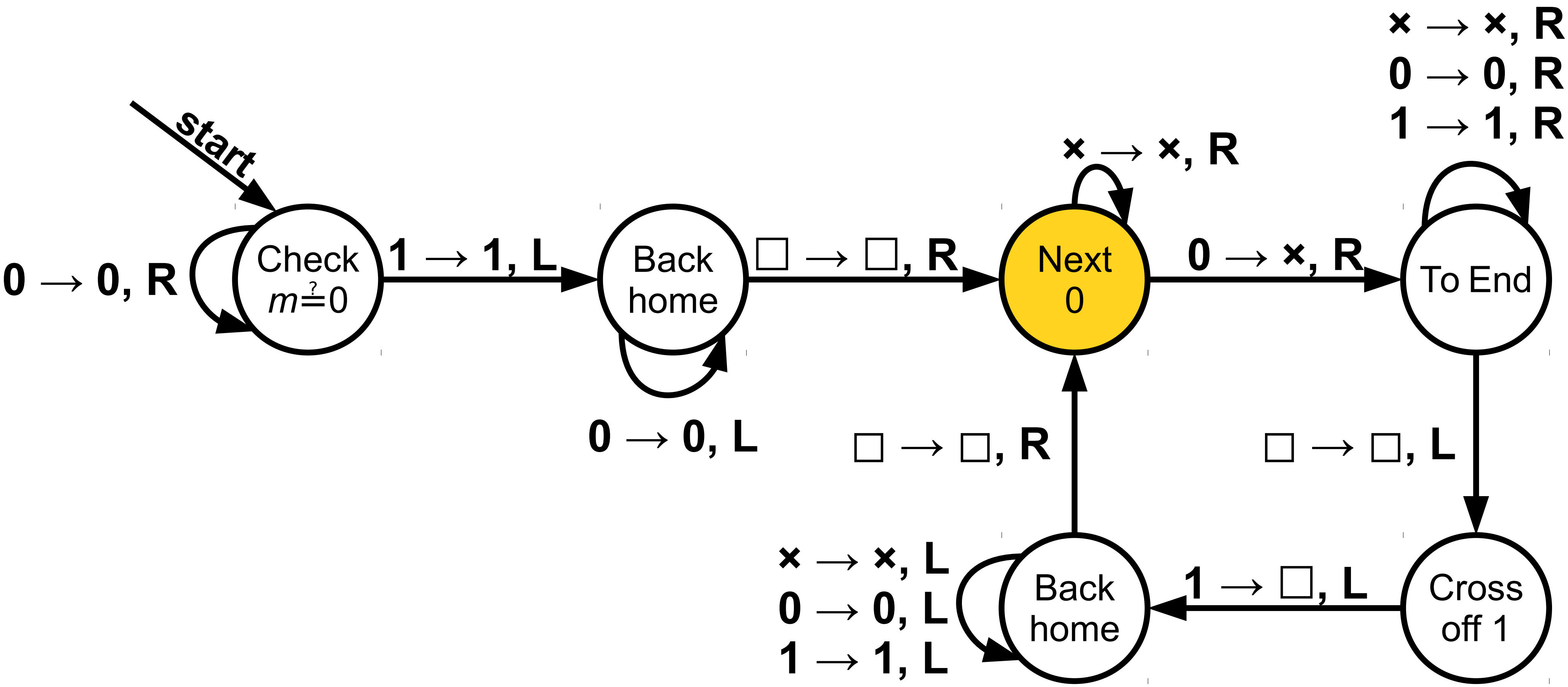
…				×	×	1	1	1	1				…

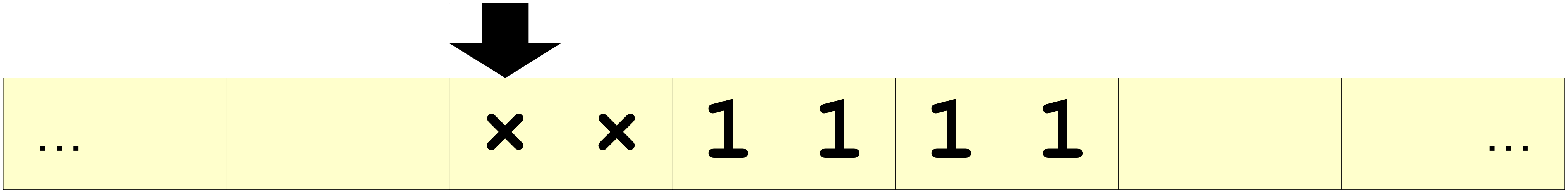

start
0 → 0, R
Check
m≟0
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
× → ×, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R

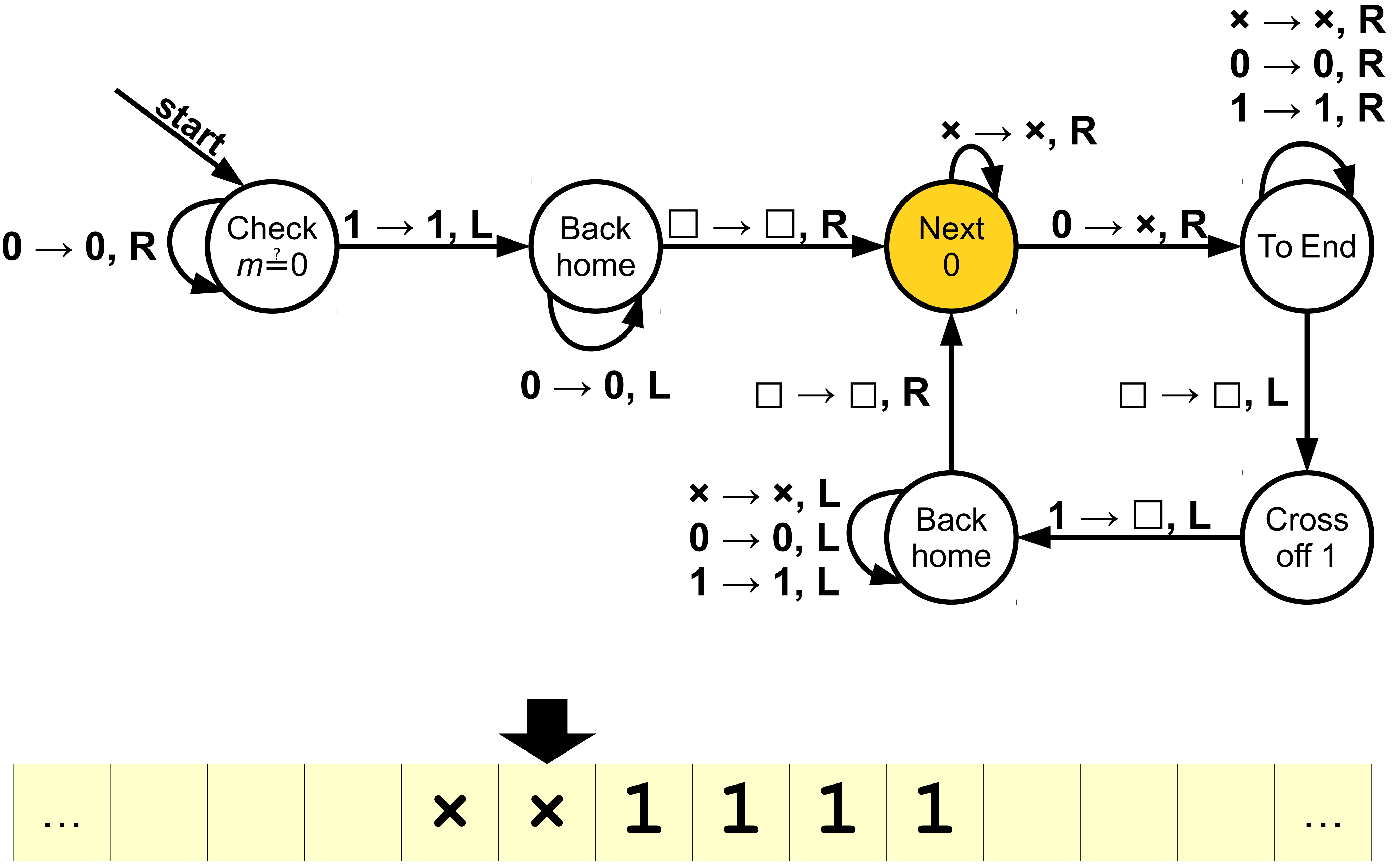
…				×	×	1	1	1	1				…


start
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
0 → 0, L
□ → □, R
× → ×, R
Next
0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, L
□ → □, R
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
×
1
1
1
1
…

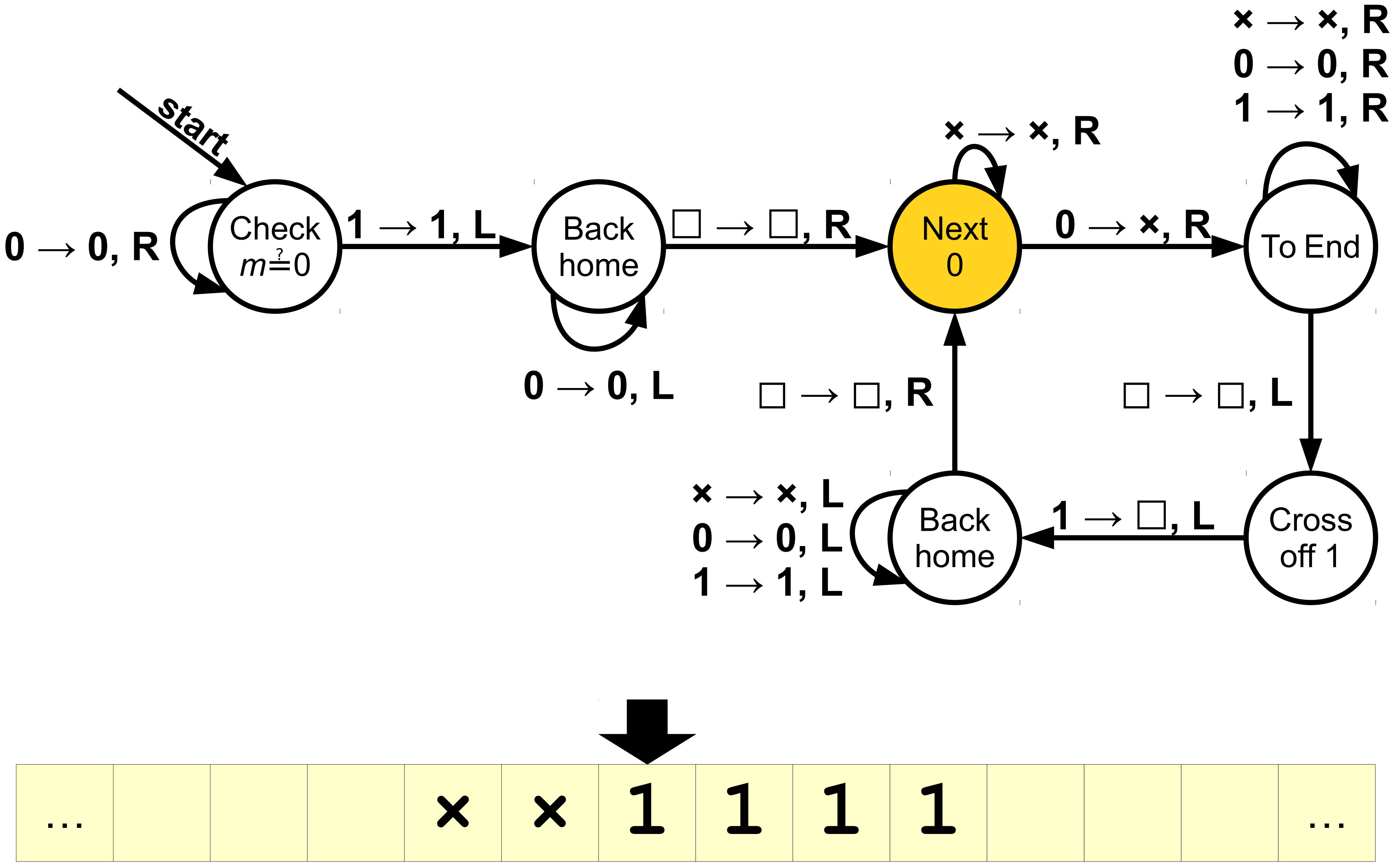

start
Check
m≟0
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
× → ×, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
1
1
1
1
…


start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
0 → 0, L
□ → □, R
× → ×, R
Next
0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, L
□ → □, R
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1

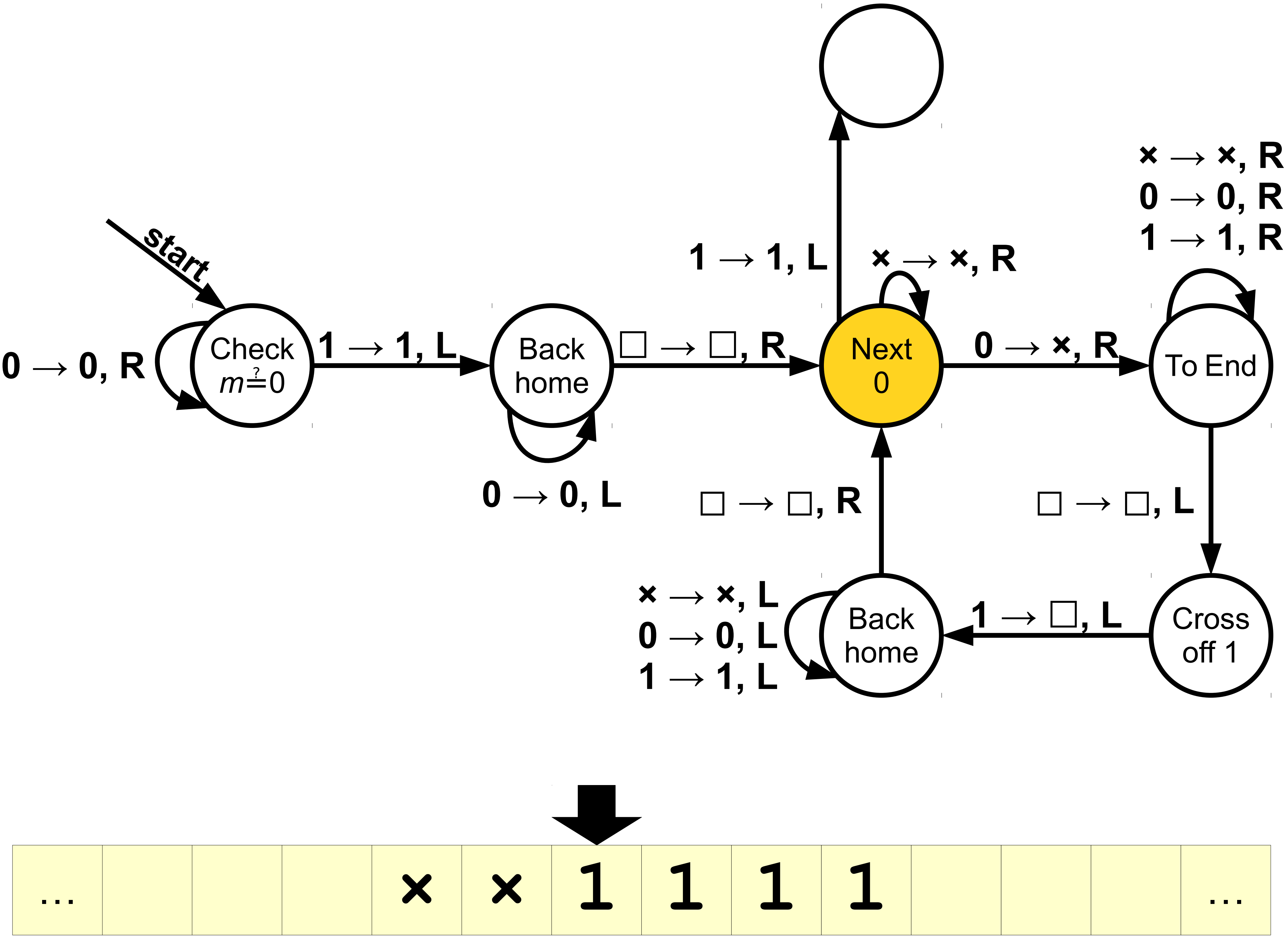

…
×
×
1
1
1
1
…

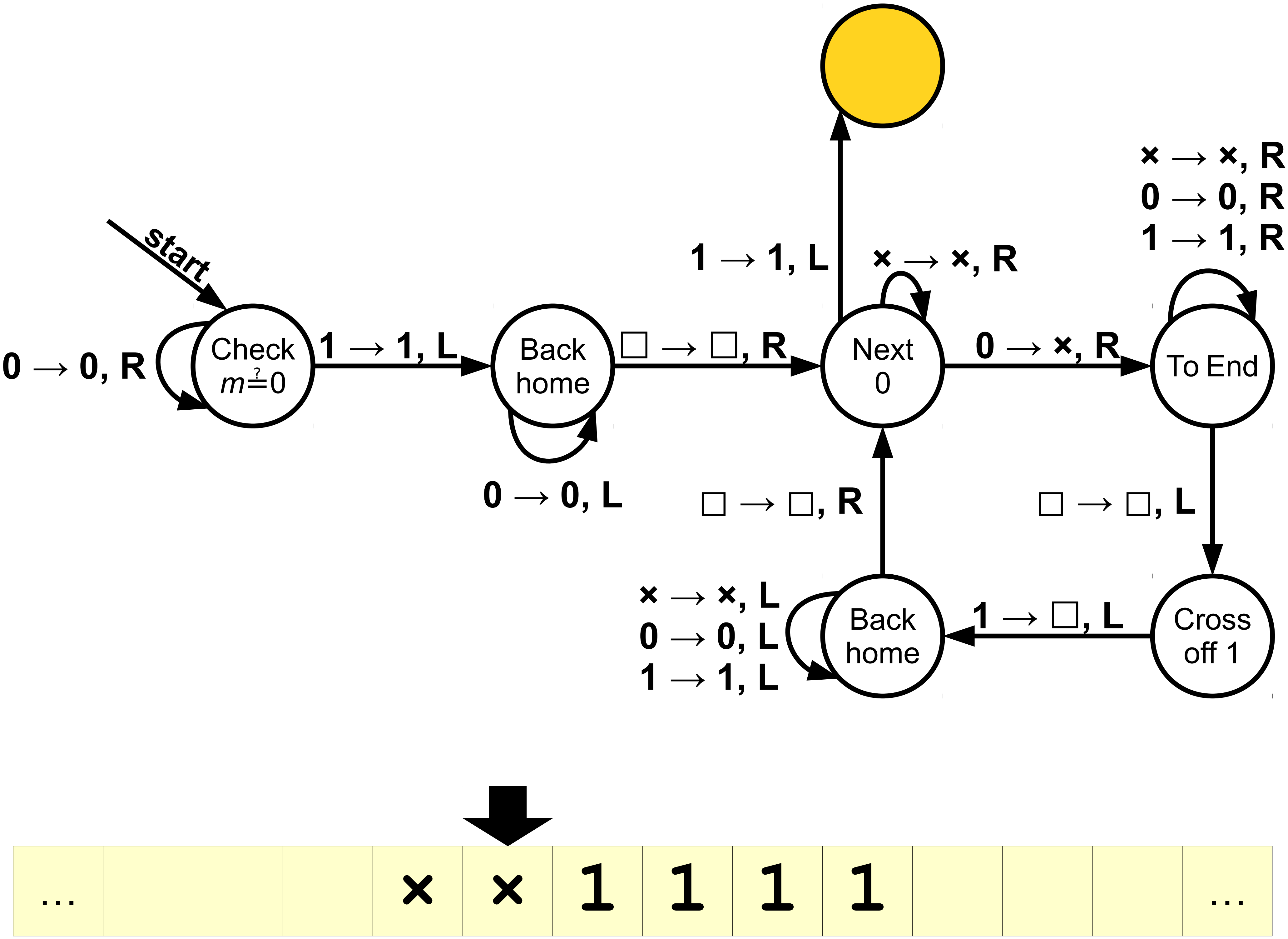

start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R

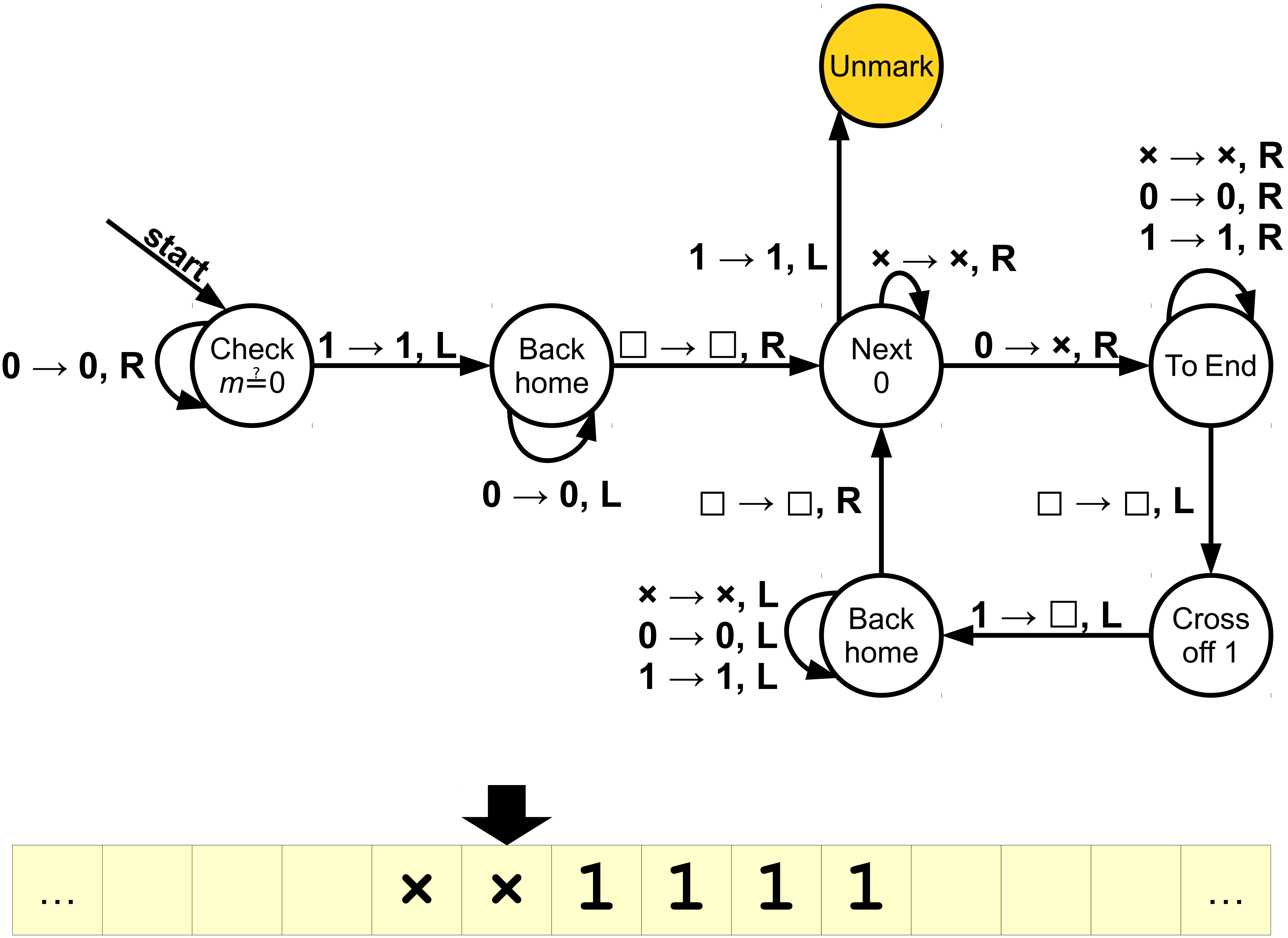
…				×	×	1	1	1	1				…

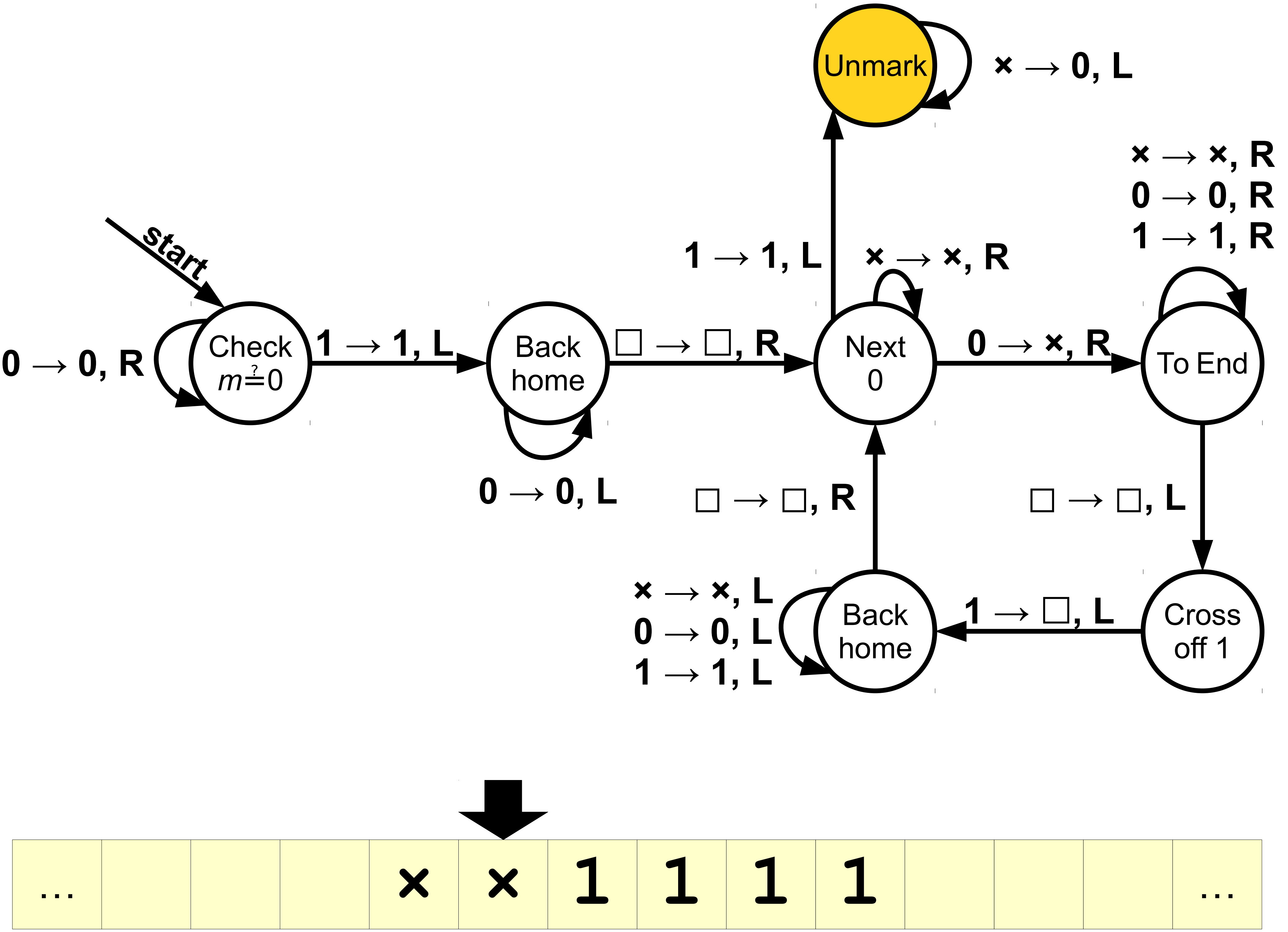

start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
0 → 0, L
□ → □, R
× → ×, R
Next
0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, L
□ → □, R
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1

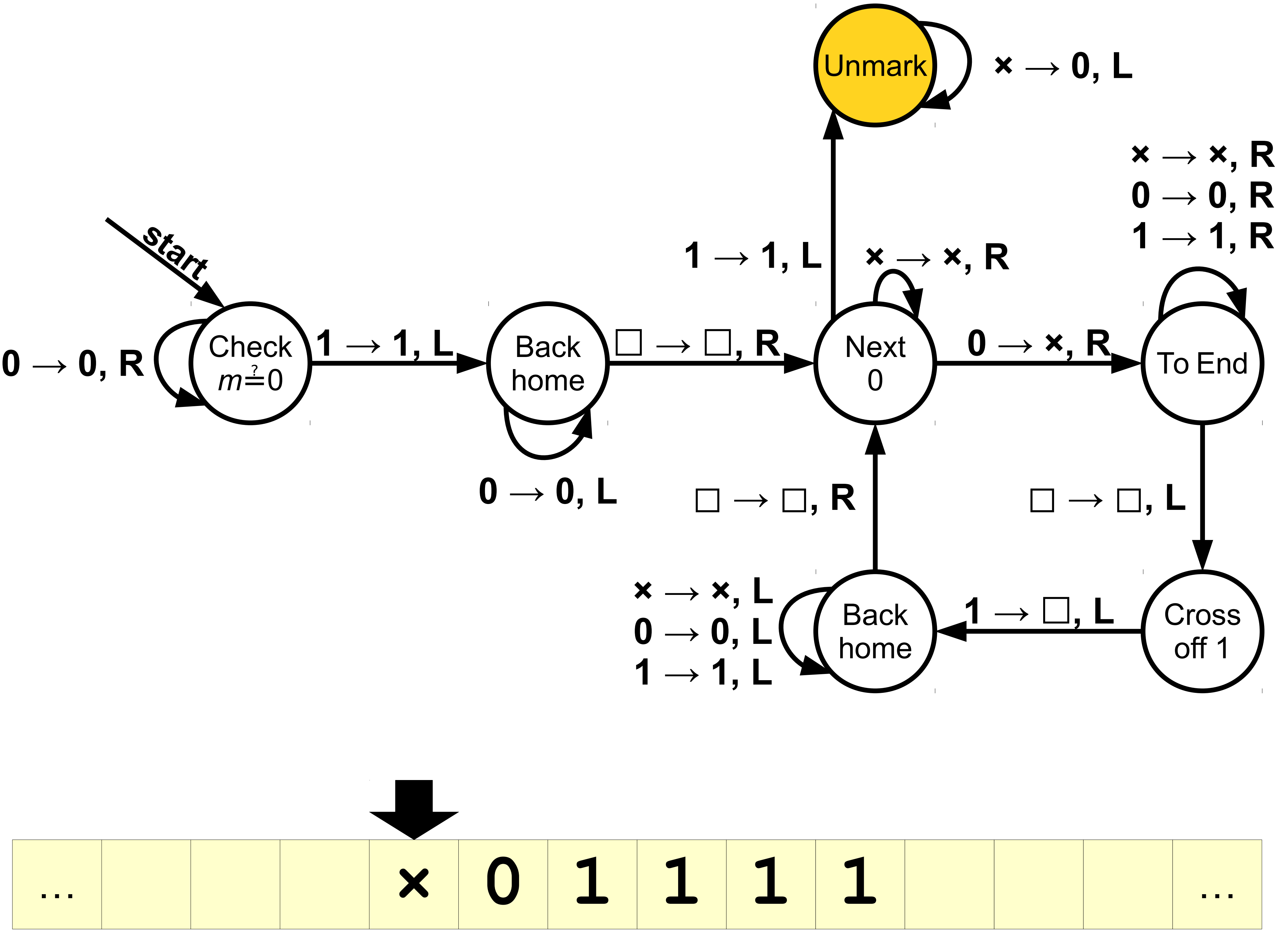
…				×	×	1	1	1	1				…


start
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
0 → 0, L
□ → □, R
1 → 1, L
× → ×, R
Next
0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
1
1
1
1
…

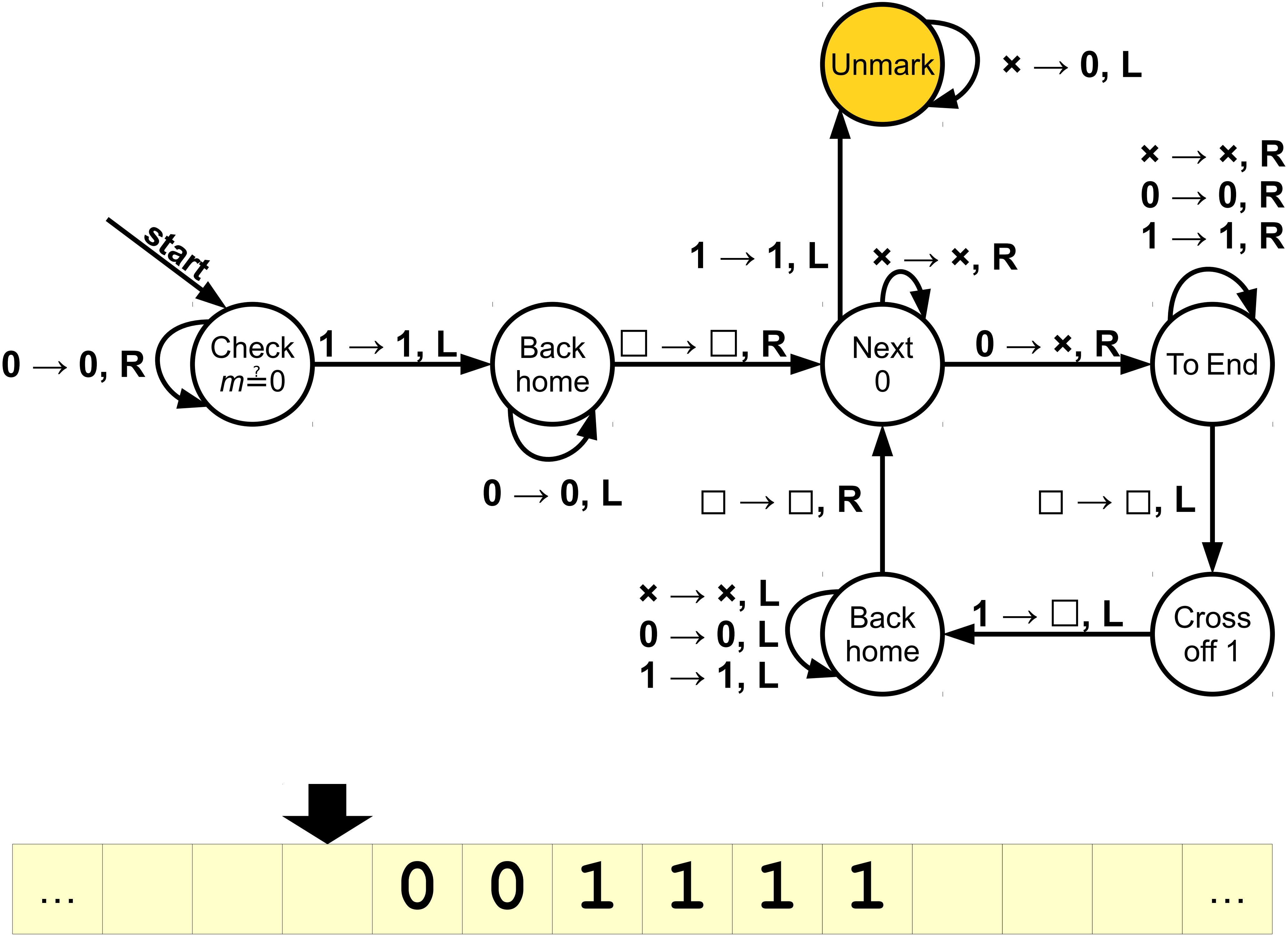

start
0 → 0, R
Check
m≟0
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
1 → 1, L
× → ×, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
1
1
1
1
…


start
Check
m ≟ 0
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Unmark
1 → 1, L
× → ×, R
Next
0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
1
1
1
1
…

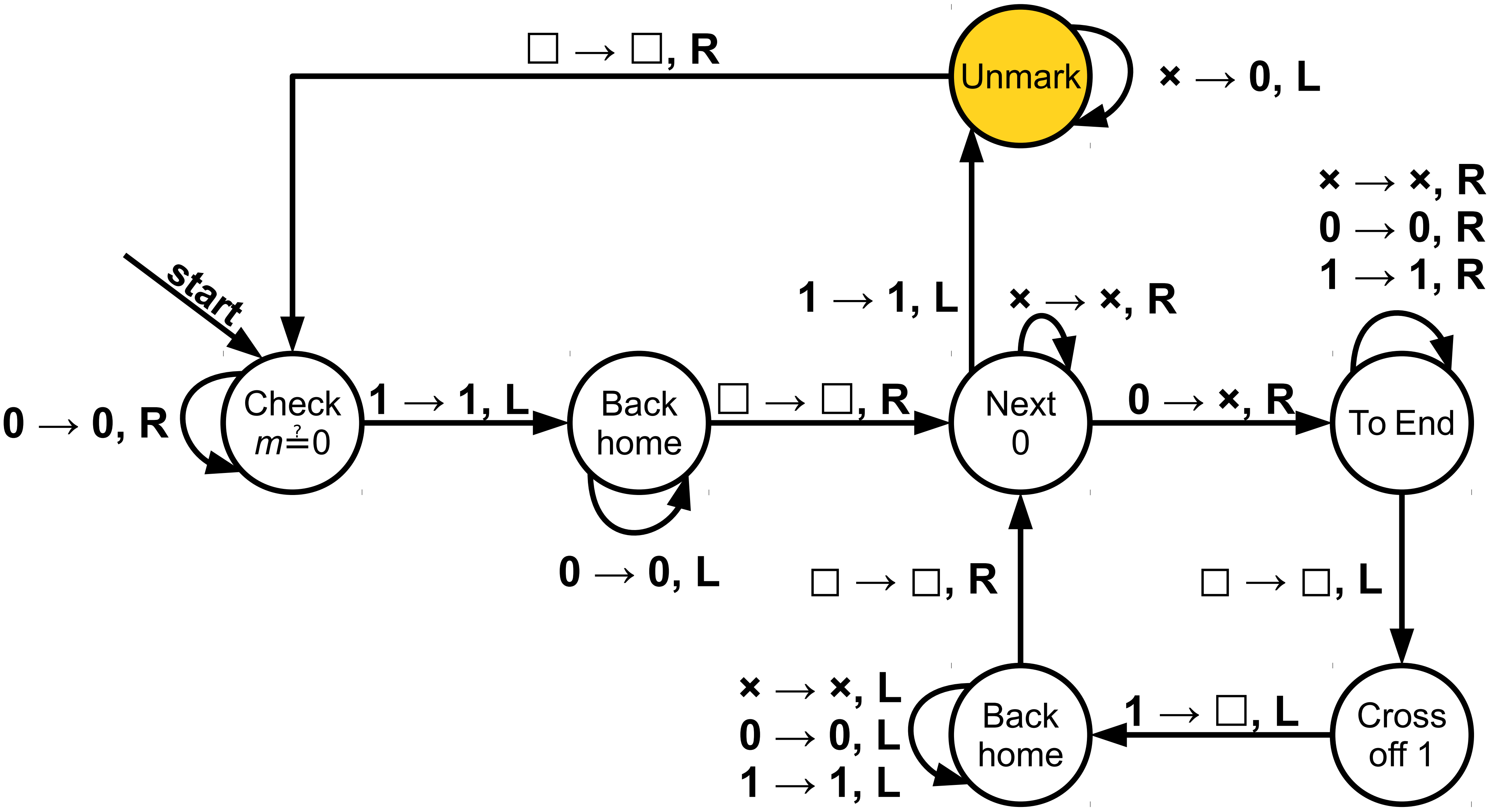

start
Check
m≟0
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
× → ×, R
1 → 1, L
Unmark
× → 0, L
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
1
1
1
1
…

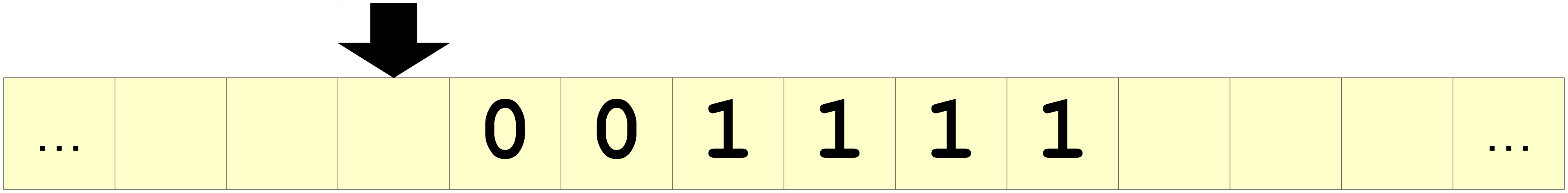

Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1

…				×	0	1	1	1	1				…

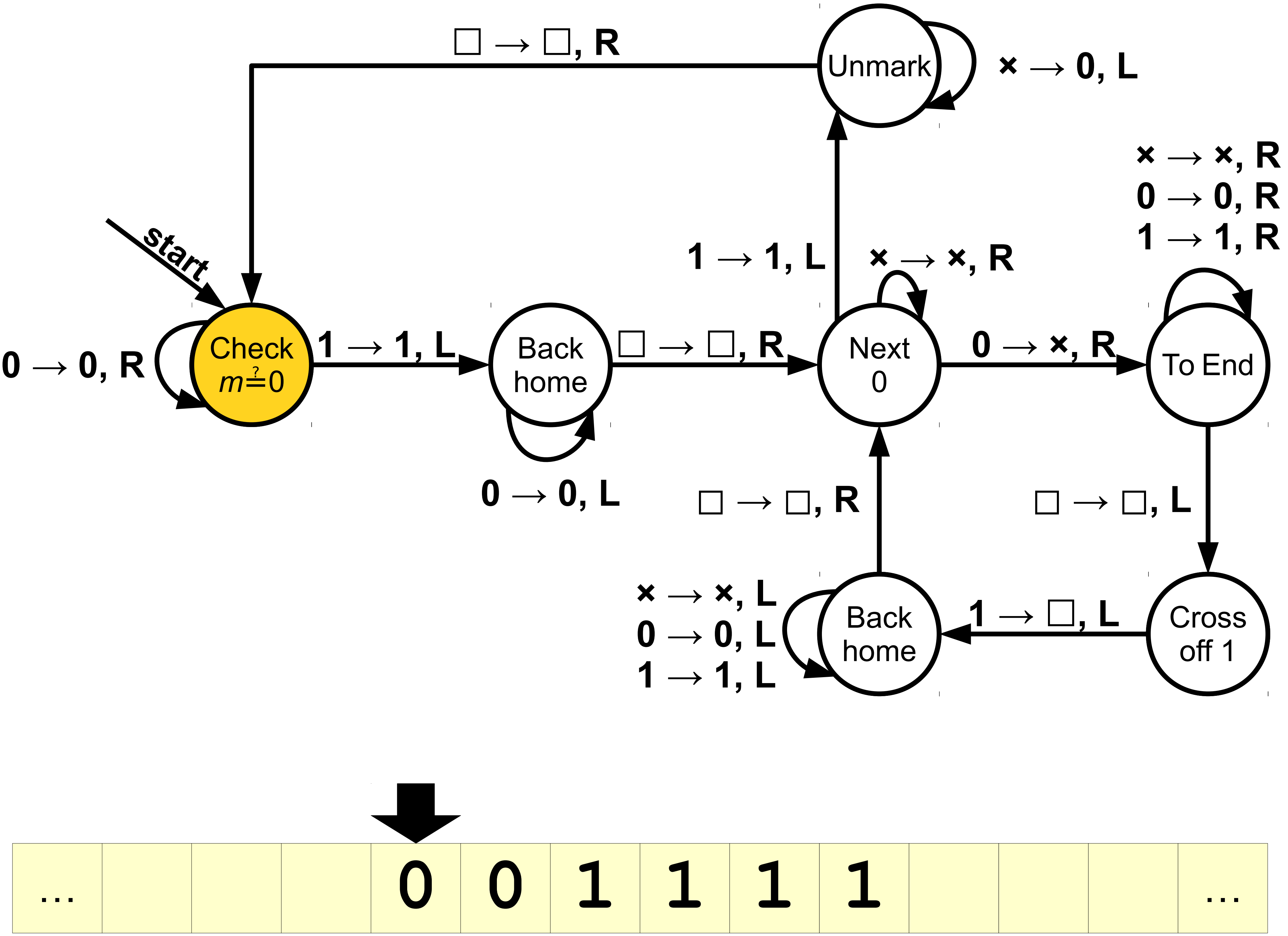


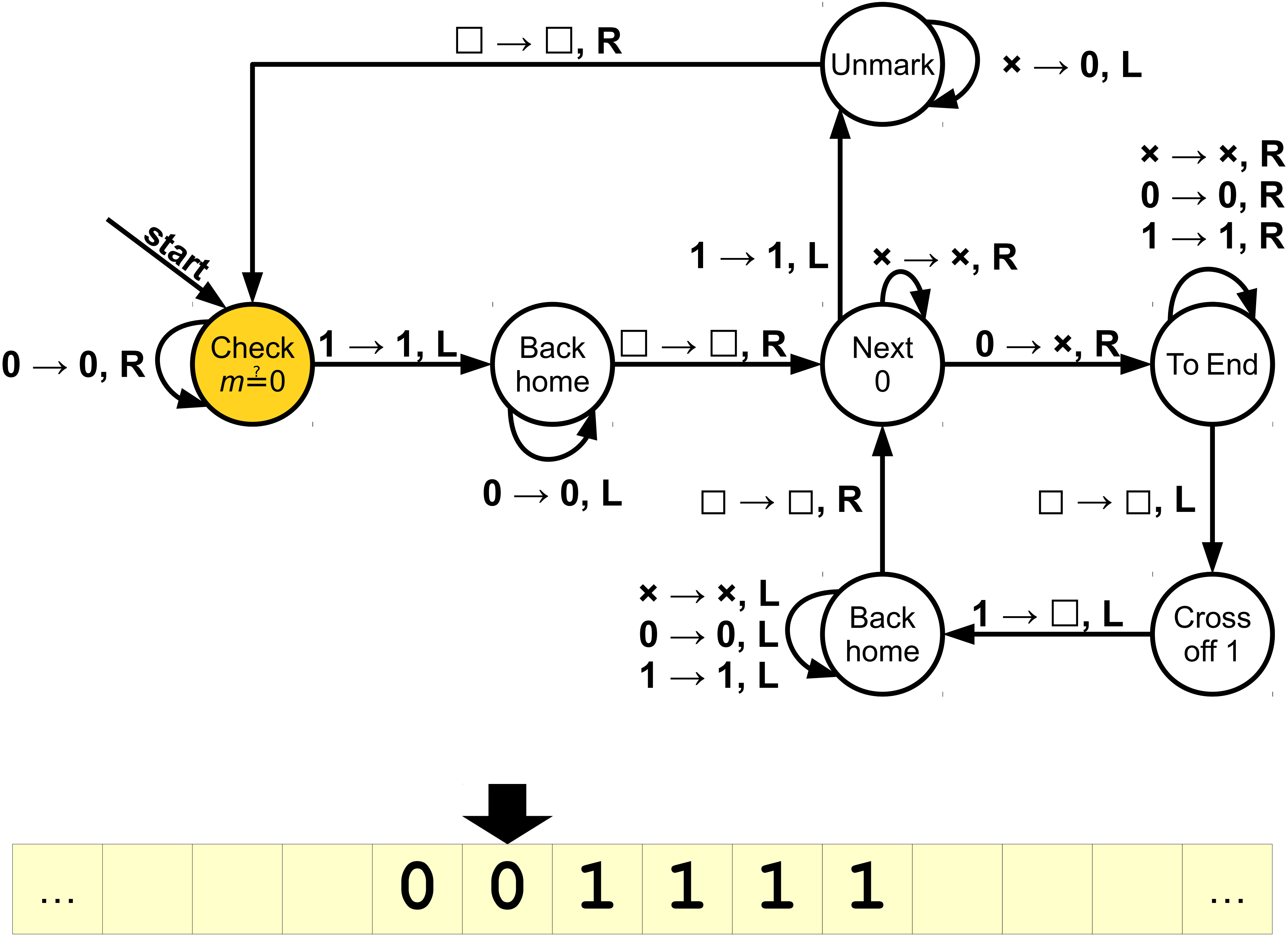
start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
1 → 1, L
Unmark
× → 0, L
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
0
0
1
1
1
1
…

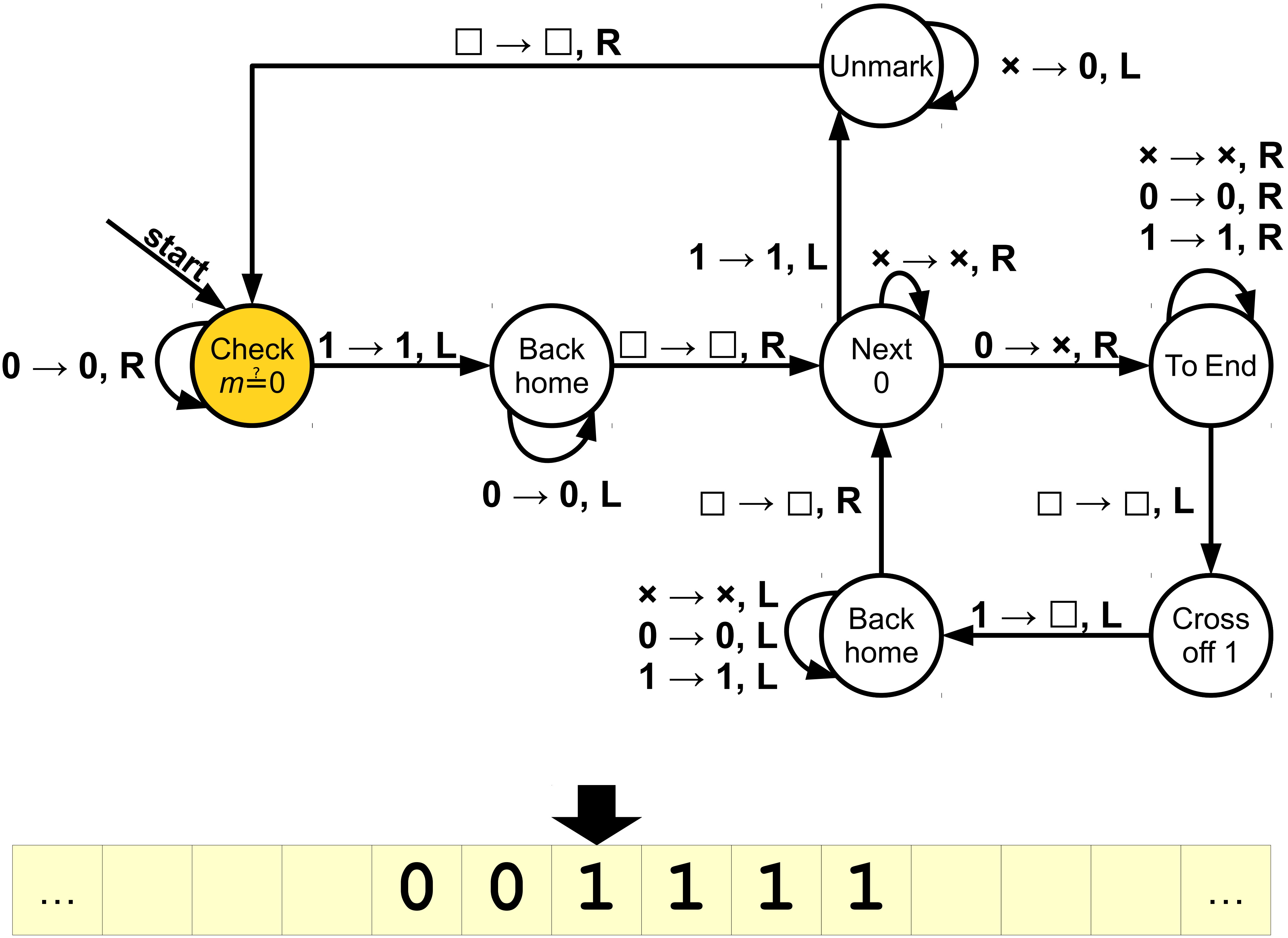

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back home
□ → □, R
Next 0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back home
1 → □, L
Cross off 1

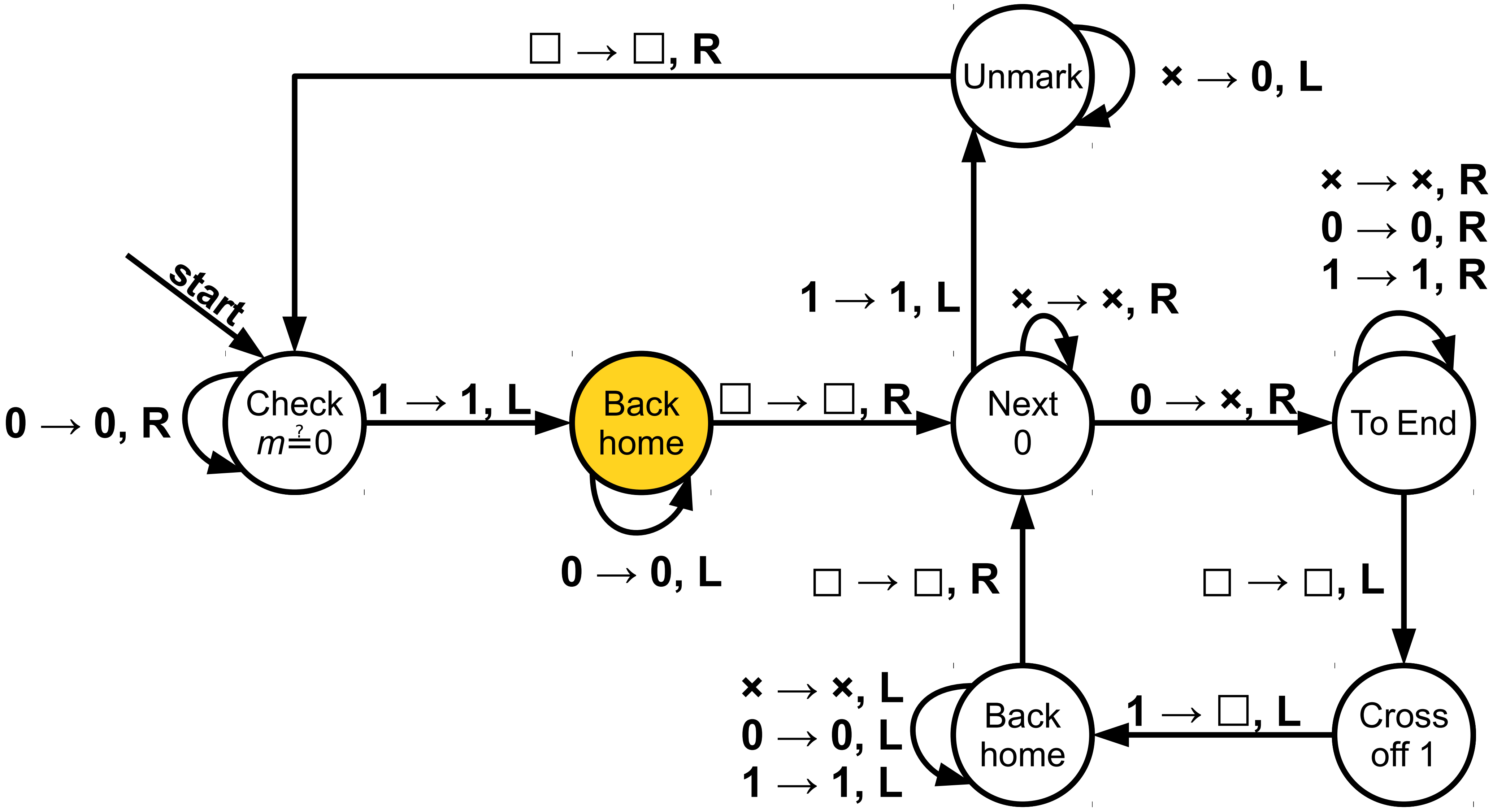


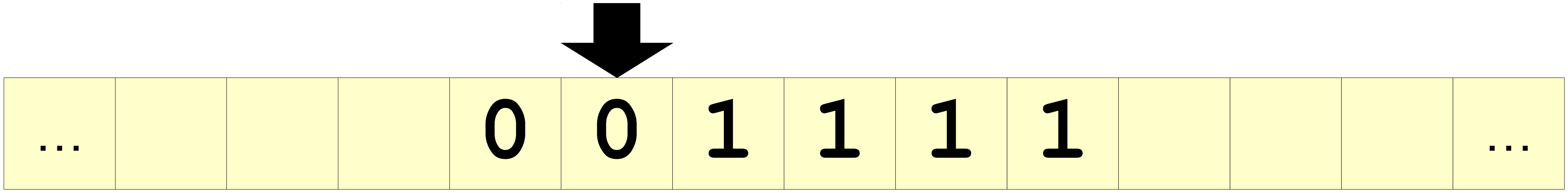
…				0	0	1	1	1	1				…


□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
start
1 → 1, L
× → ×, R
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
0
0
1
1
1
1
…

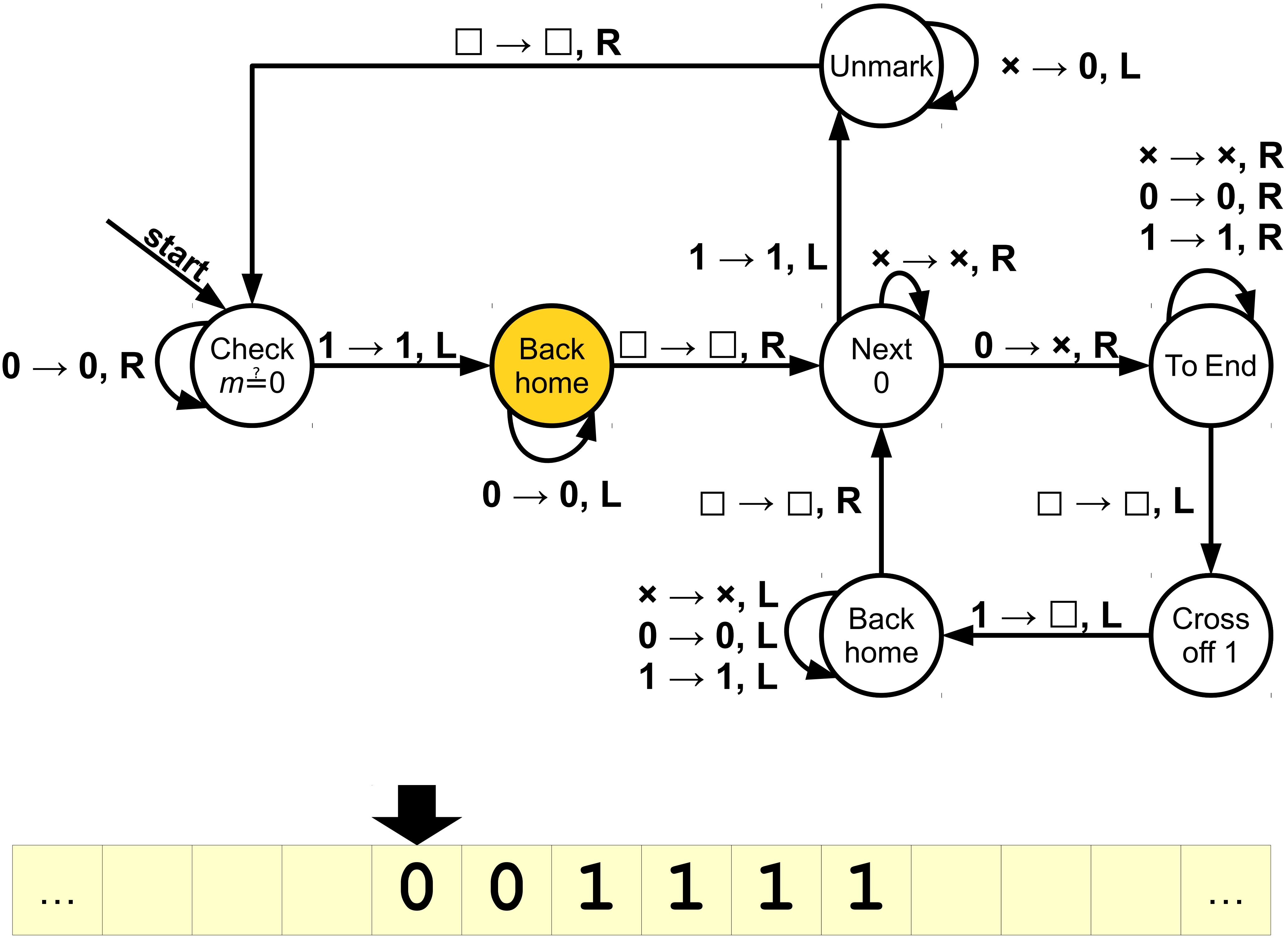

start
Check
m ≟ 0
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
× → ×, R
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
0
0
1
1
1
1
…

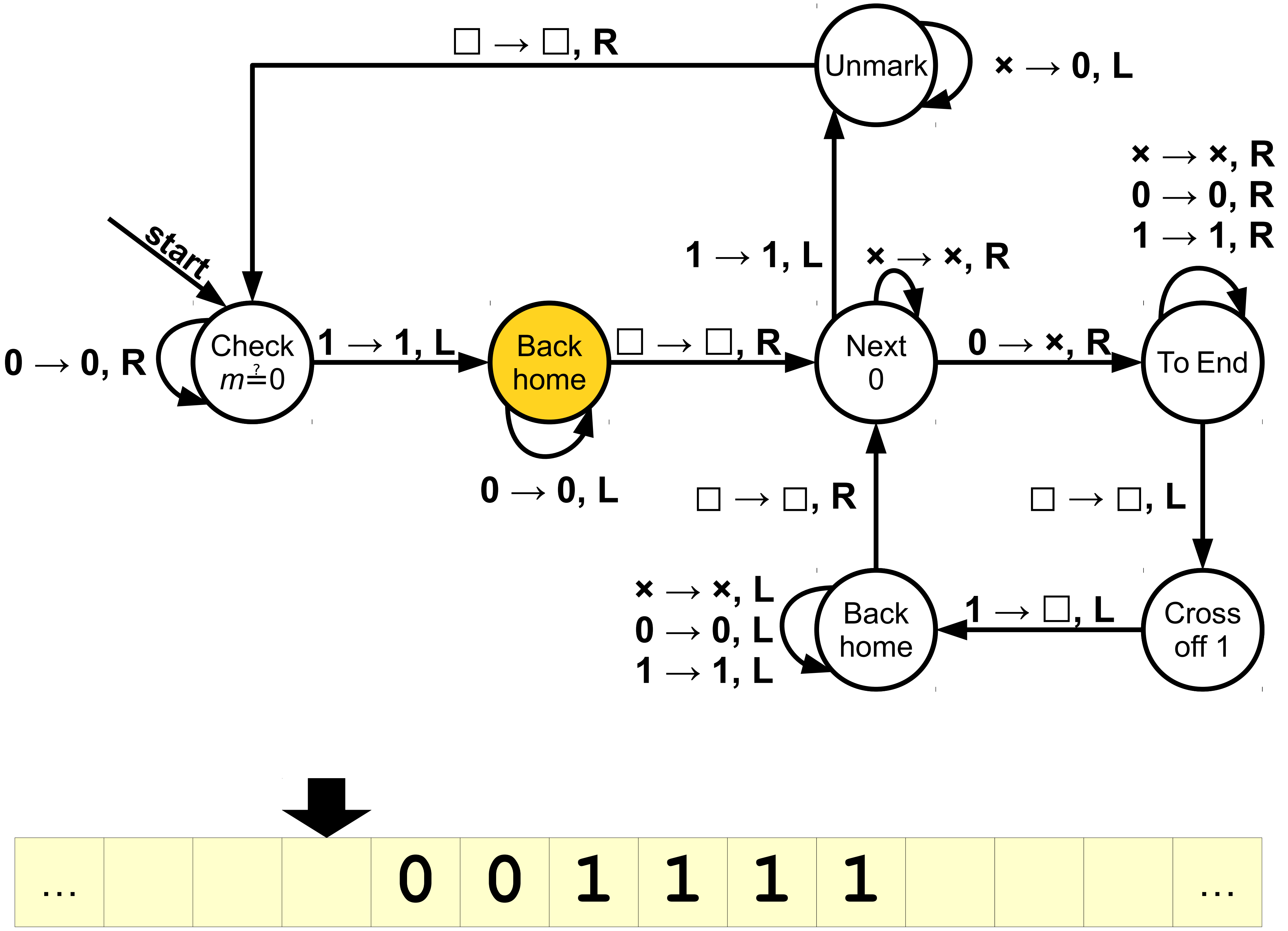

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
start
1 → 1, L
× → ×, R
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
0
0
1
1
1
1
…

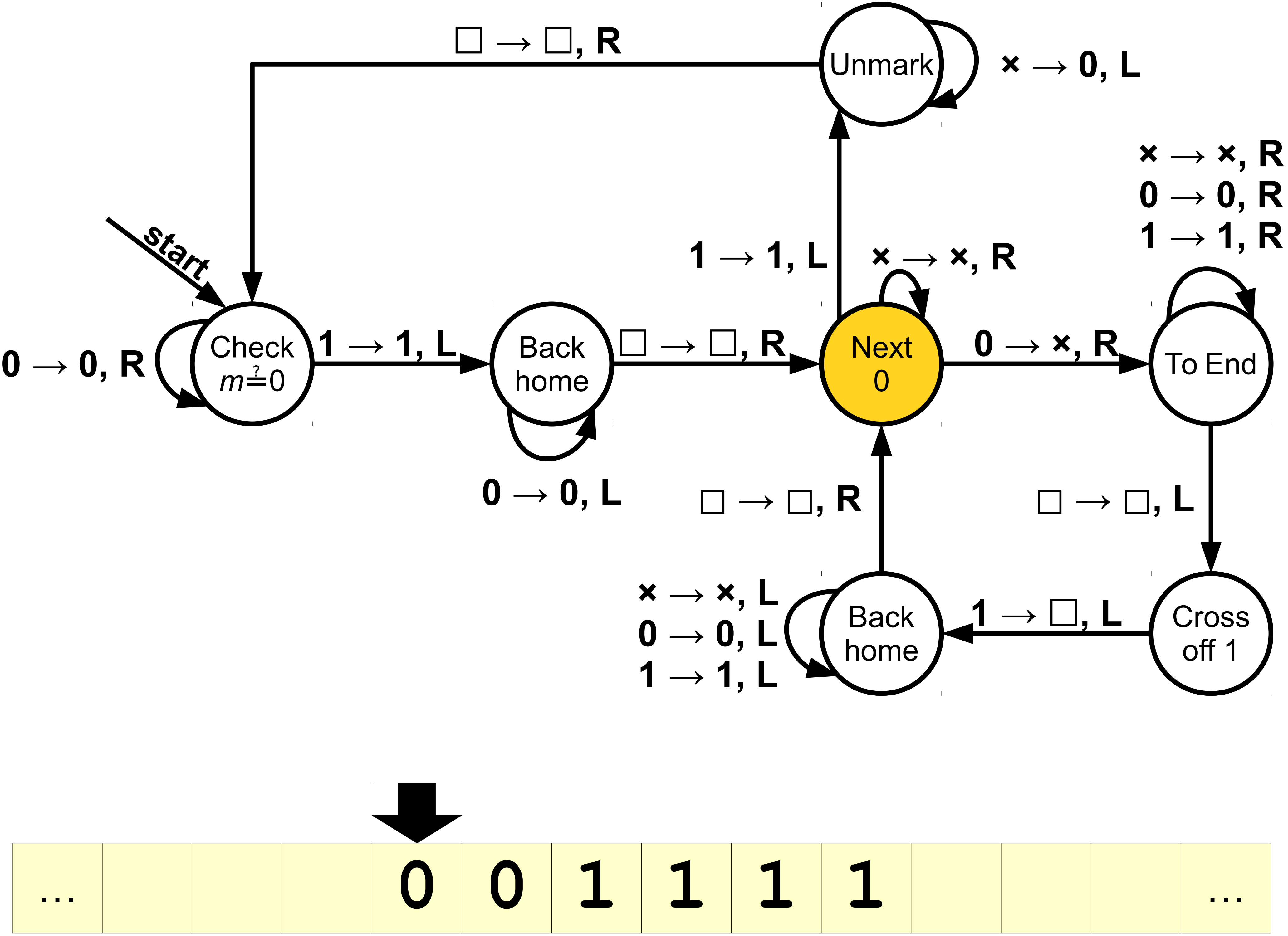

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1

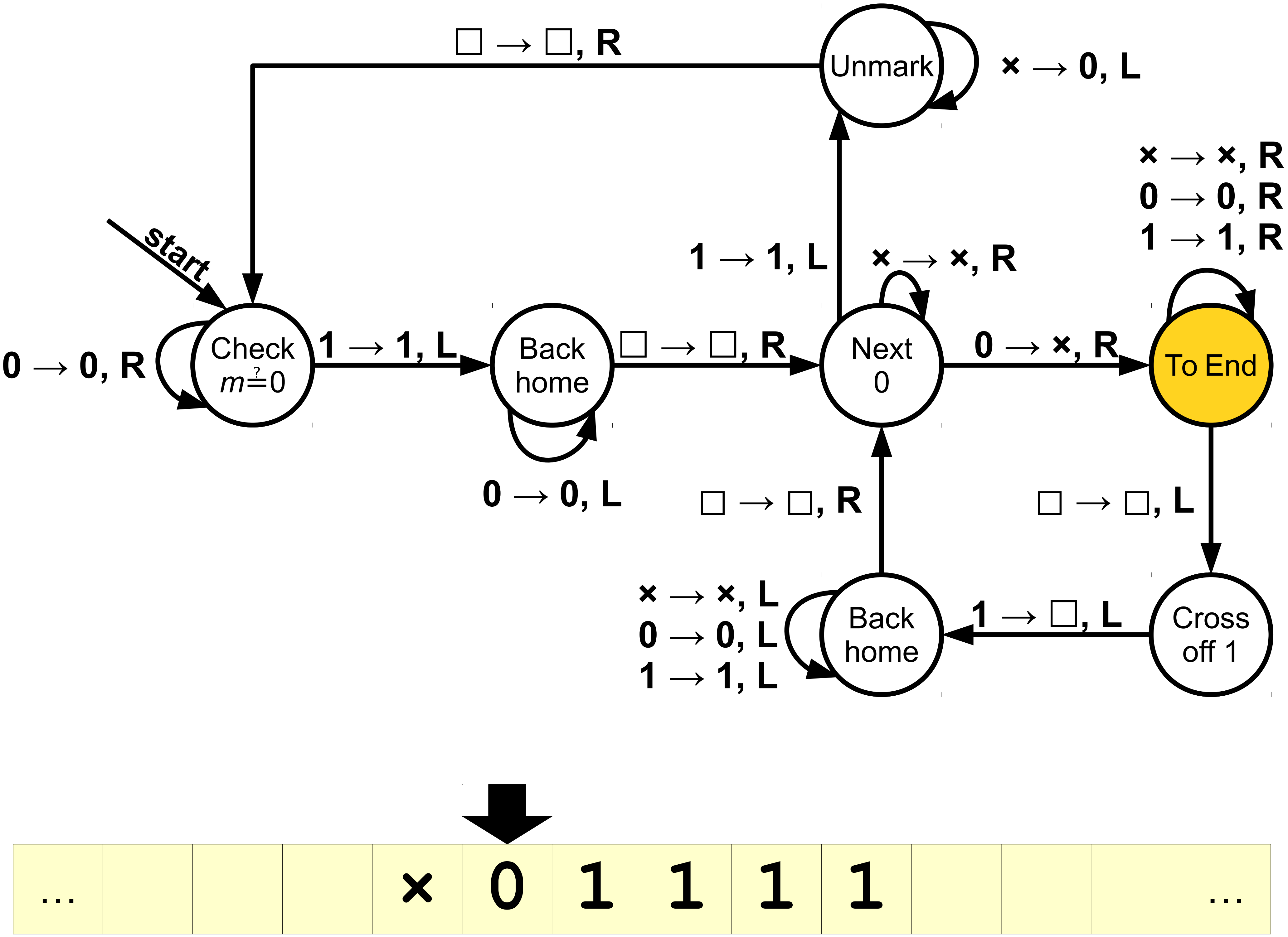


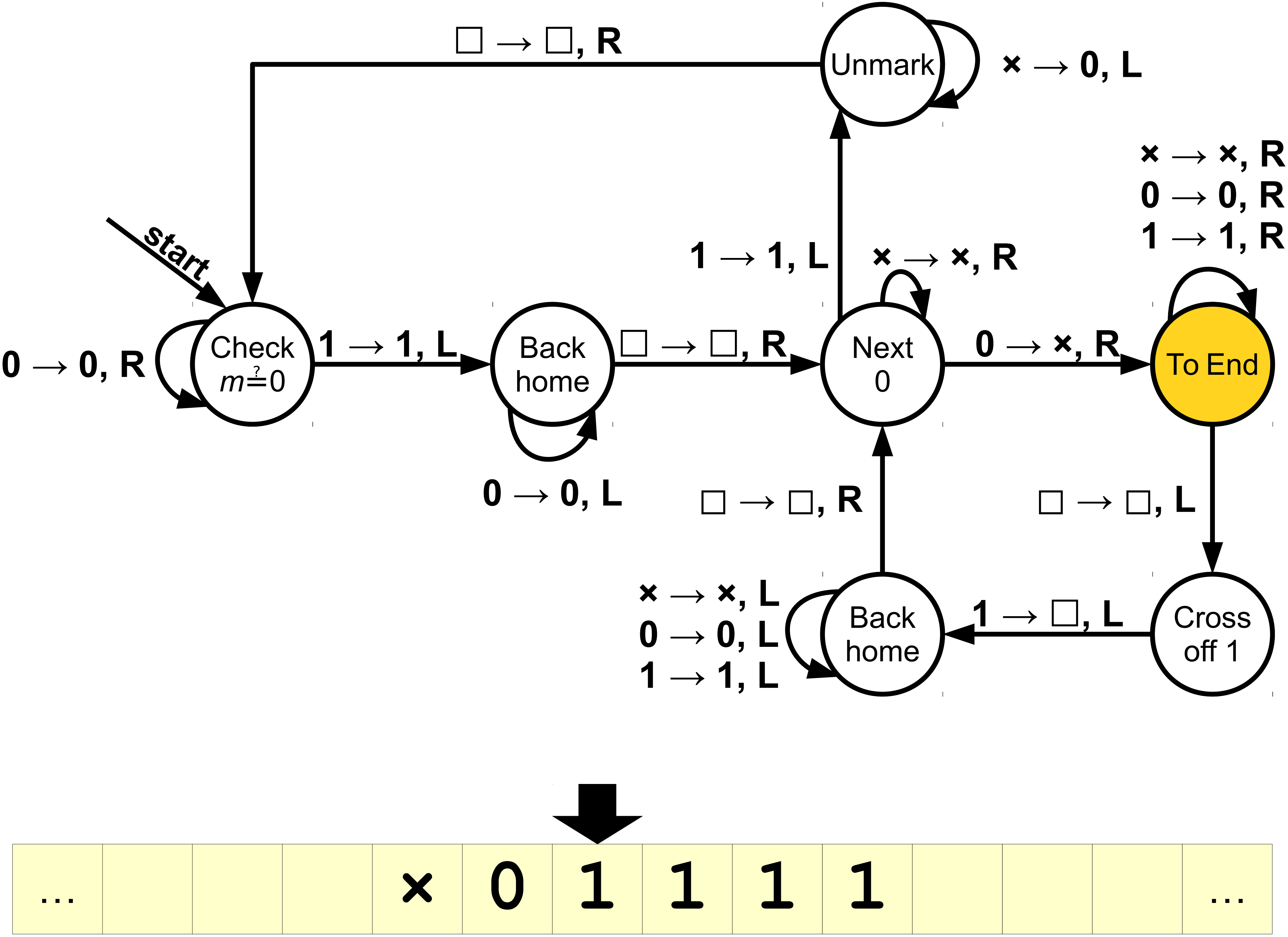
…				0	0	1	1	1	1				…

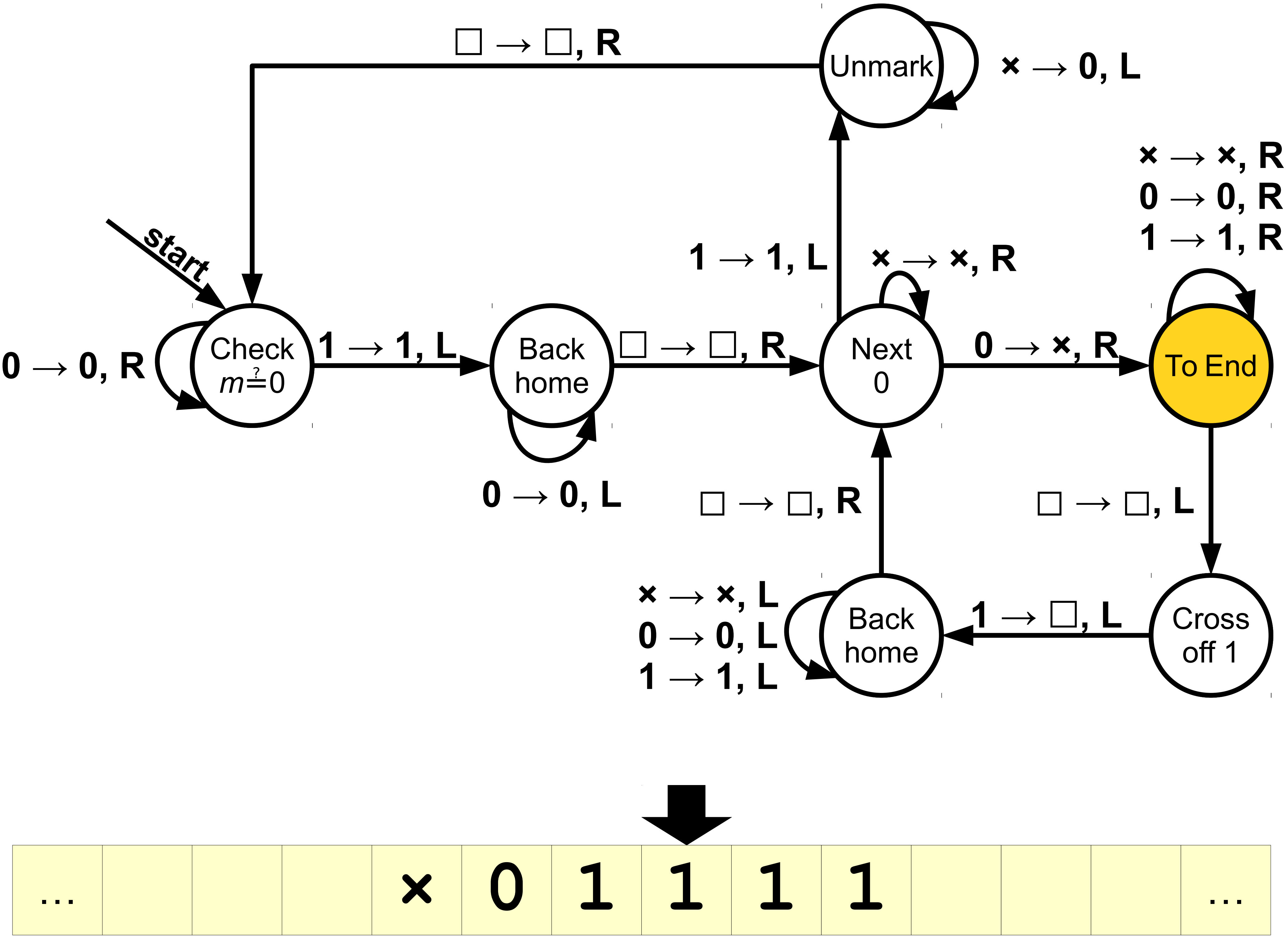

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
start
1 → 1, L
× → ×, R
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
0
0
1
1
1
1
…

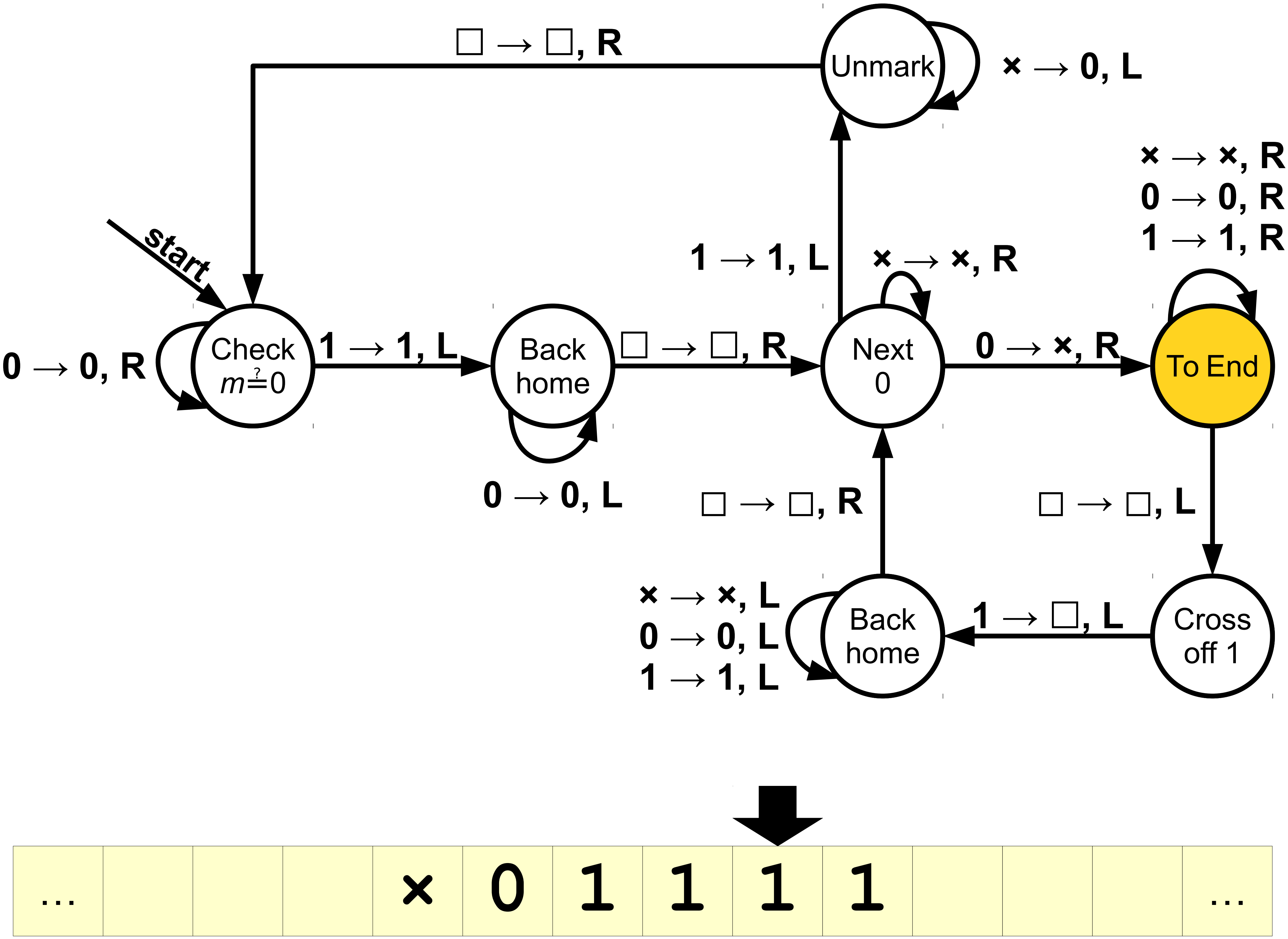

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
m≟0
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
0
0
1
1
1
1
…

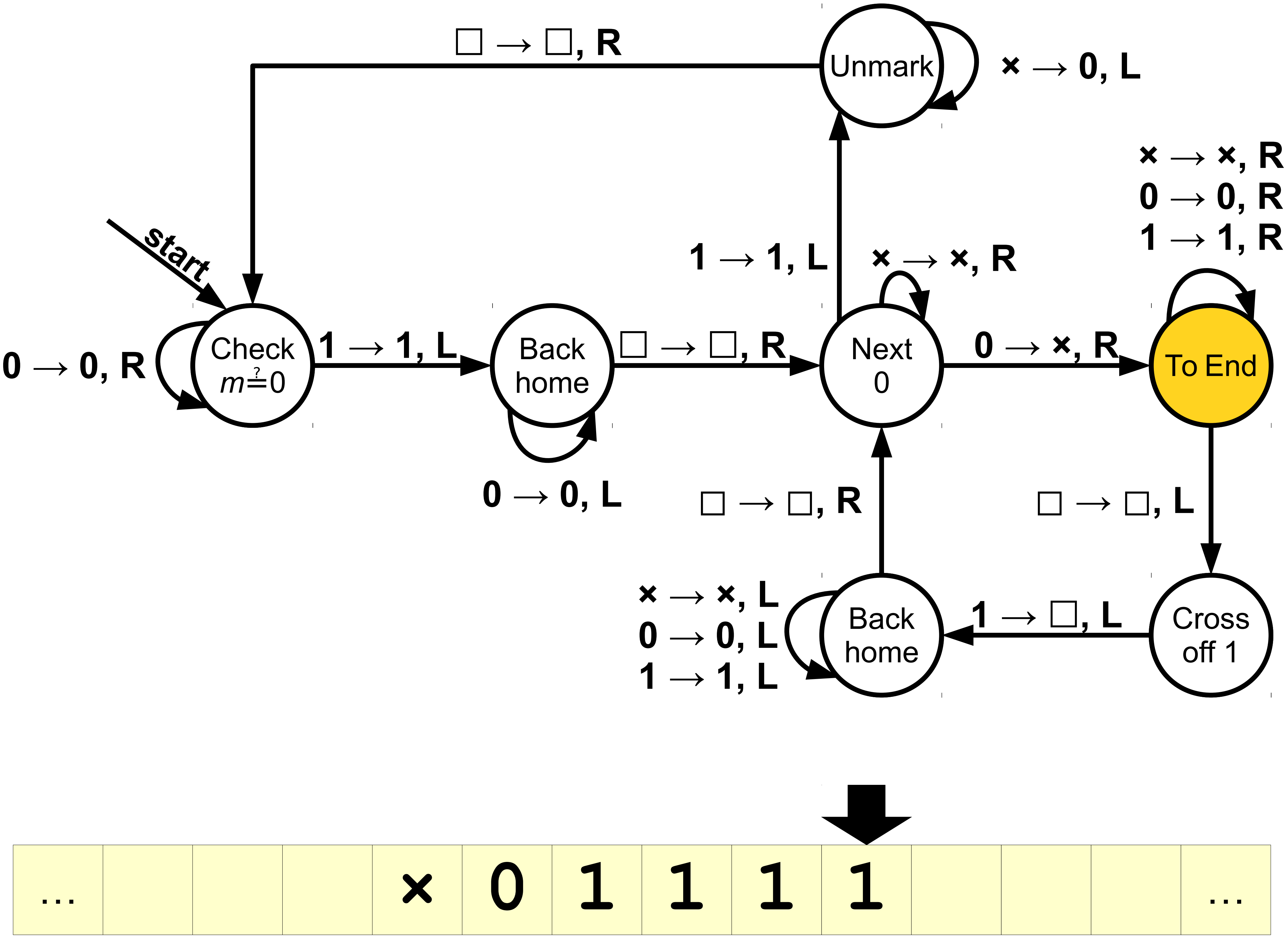

□ → □, R
Unmark
× → 0, L
start
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
0 → 0, R
Check
m≟0
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
0
0
1
1
1
1
…

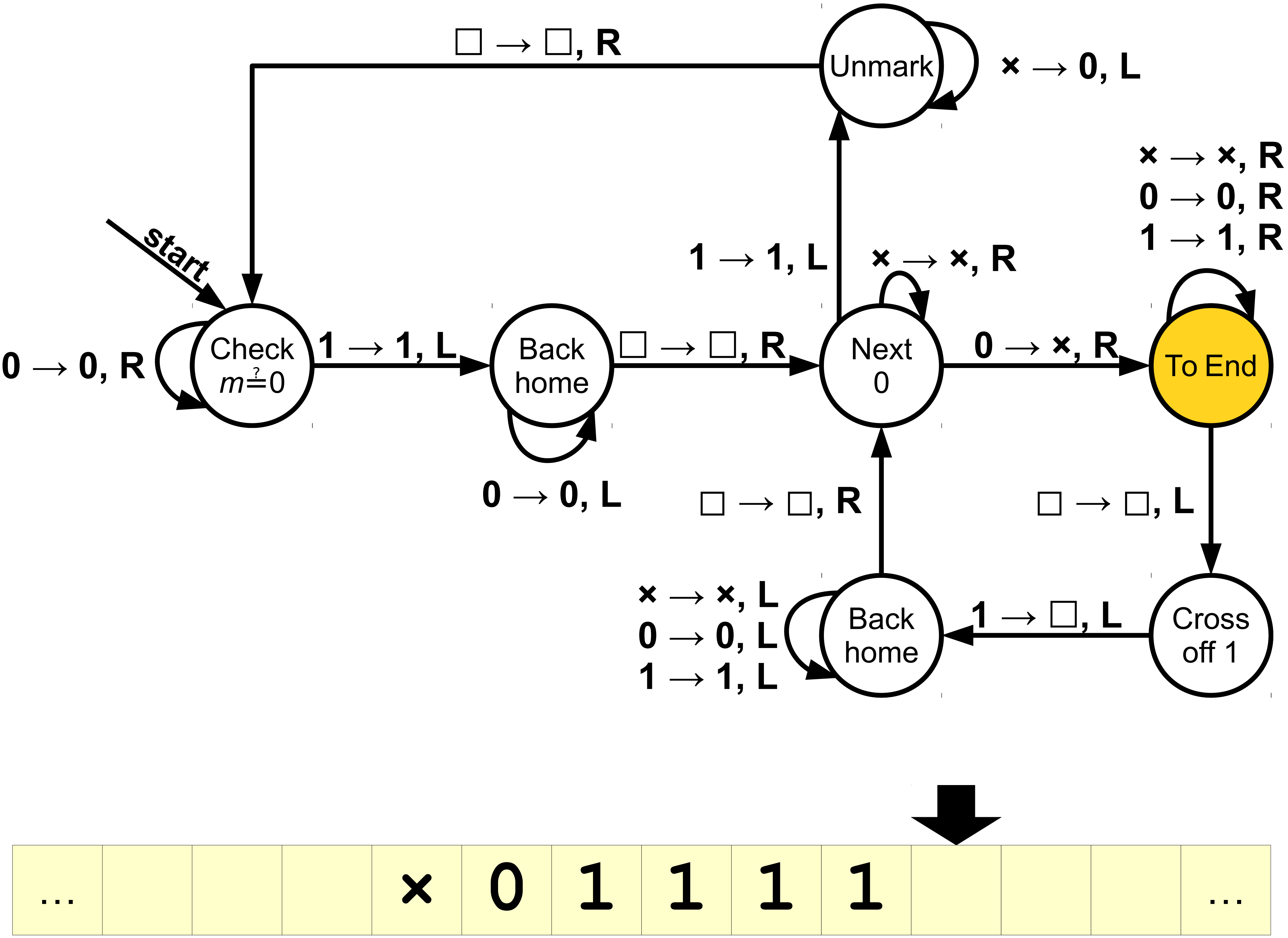

start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
1 → 1, L
× → ×, R
0 → ×, R
Unmark
× → 0, L
□ → □, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
0
1
1
1
1
…

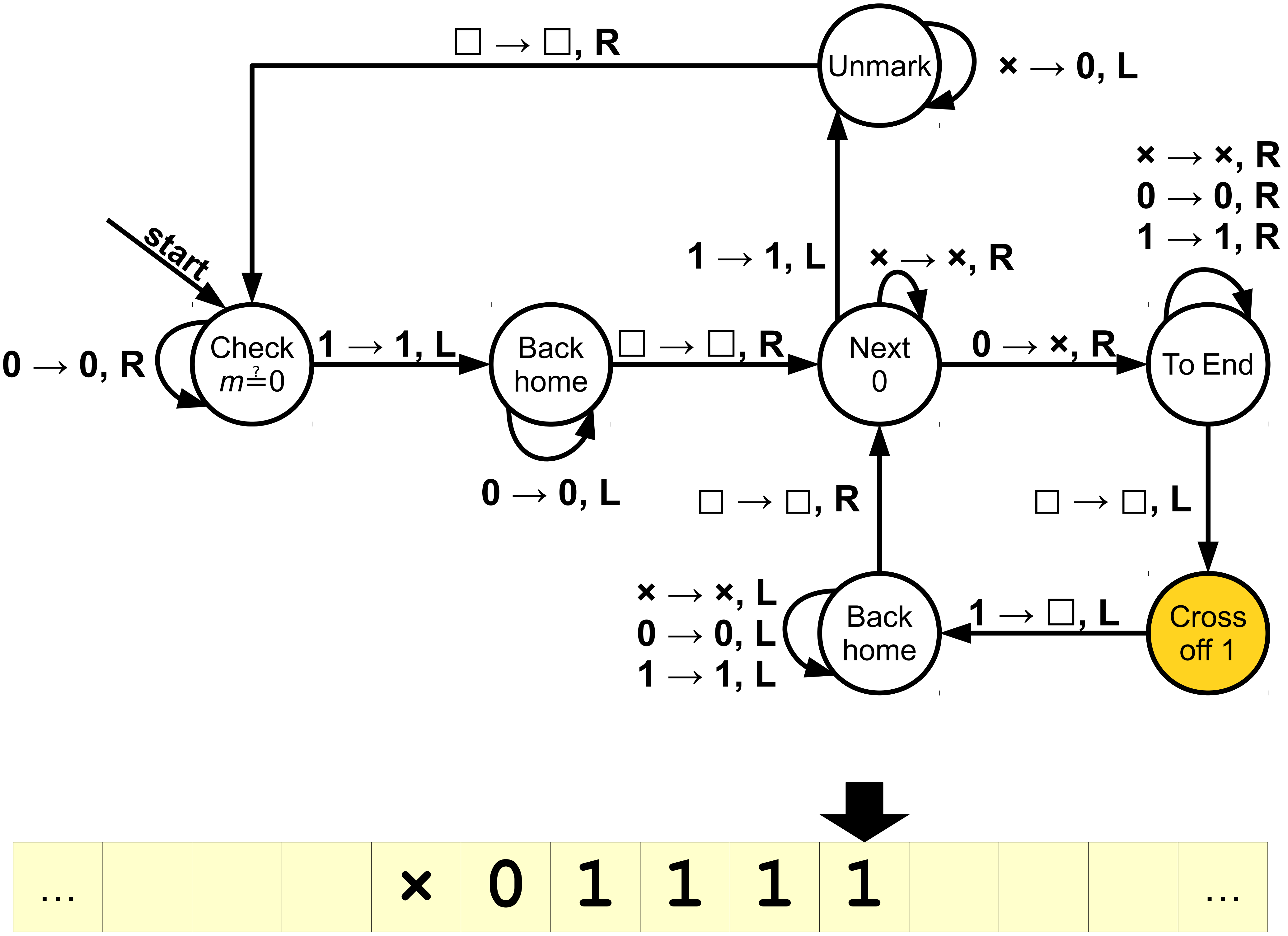

start
Check
$m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
0
1
1
1
1
…


□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
start
1 → 1, L
× → ×, R
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
1
1
1
1
…

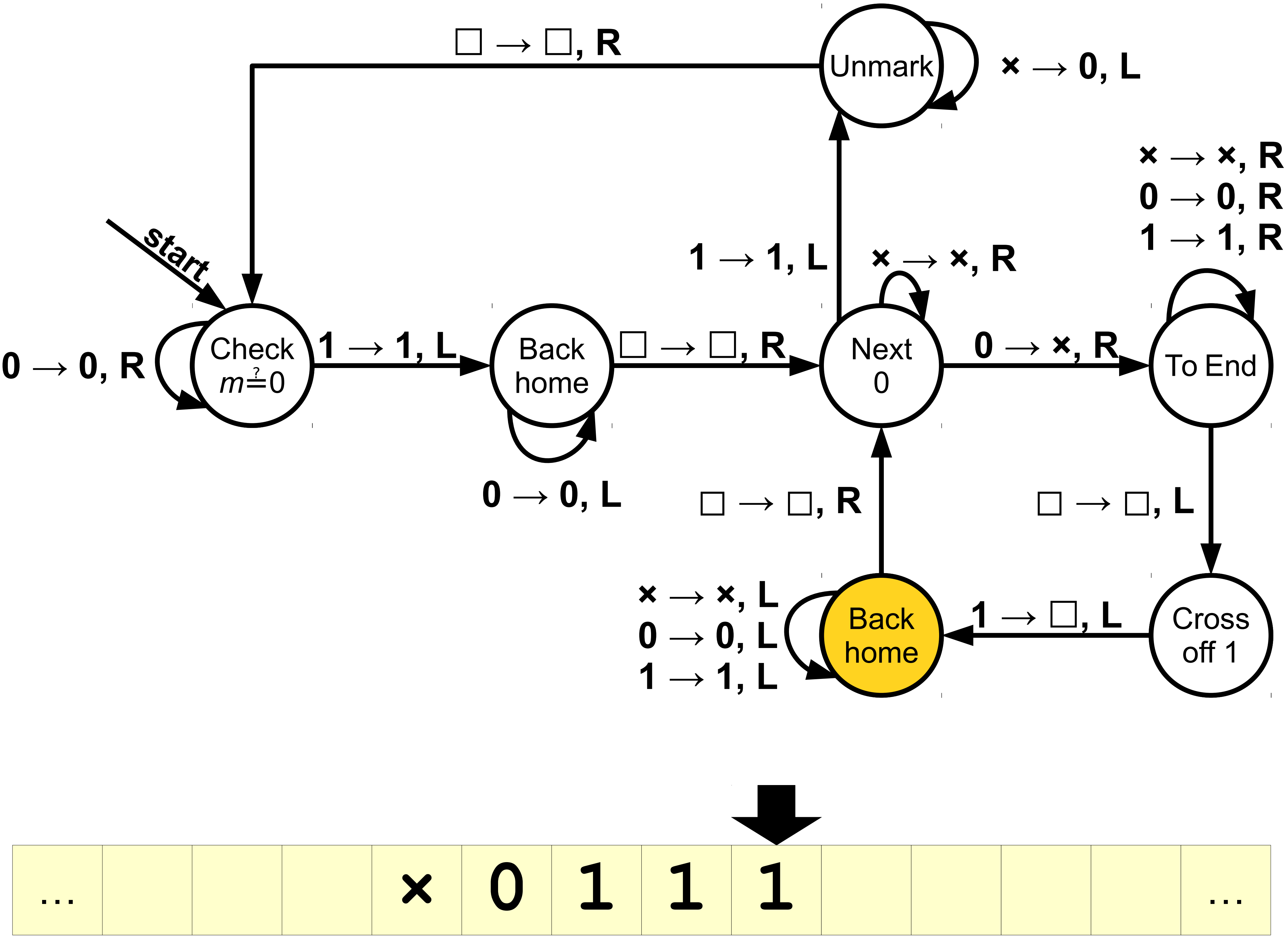

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
start
1 → 1, L
× → ×, R
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
1
1
1
1
…

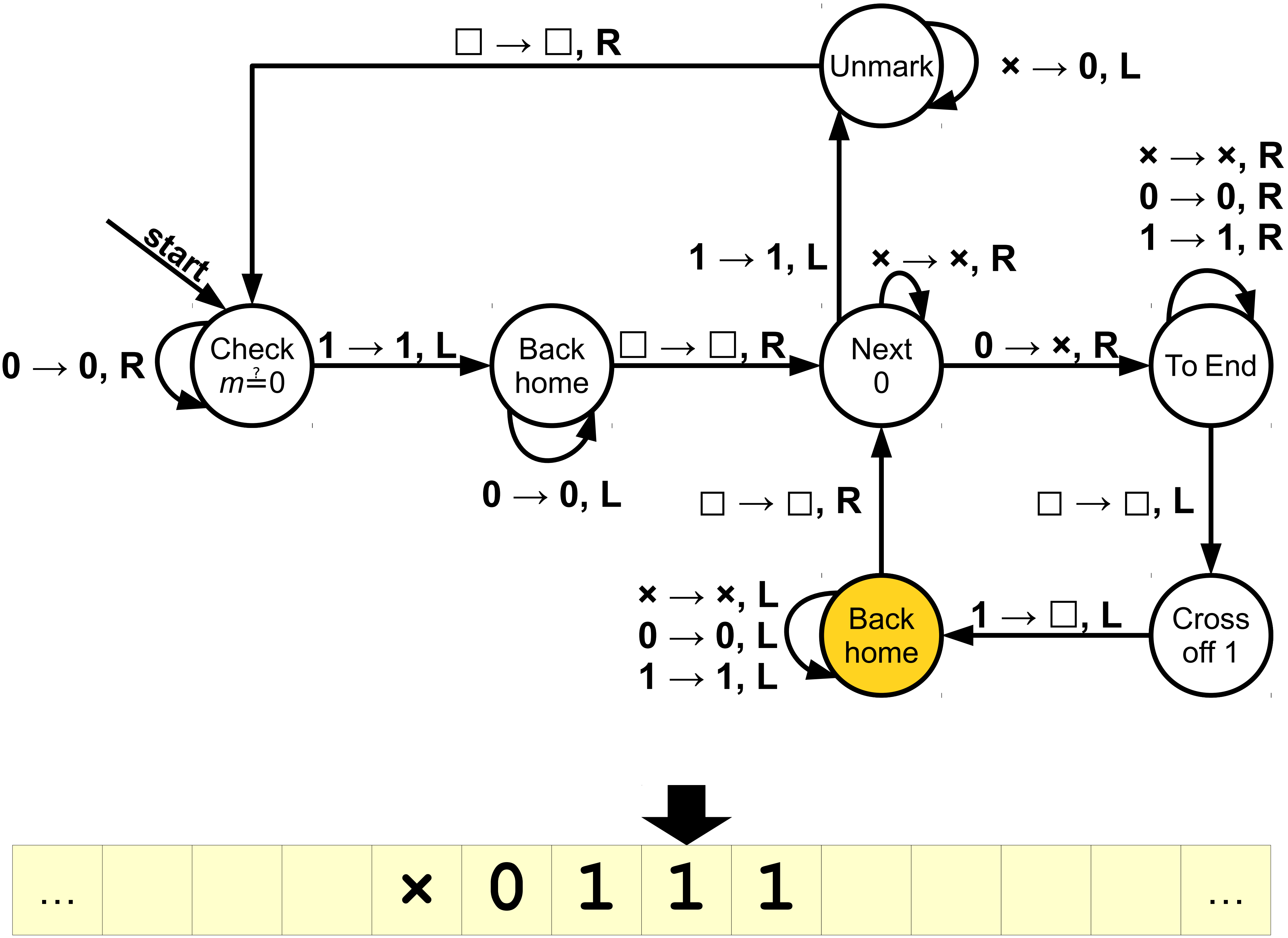

start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
0
1
1
1
1
…

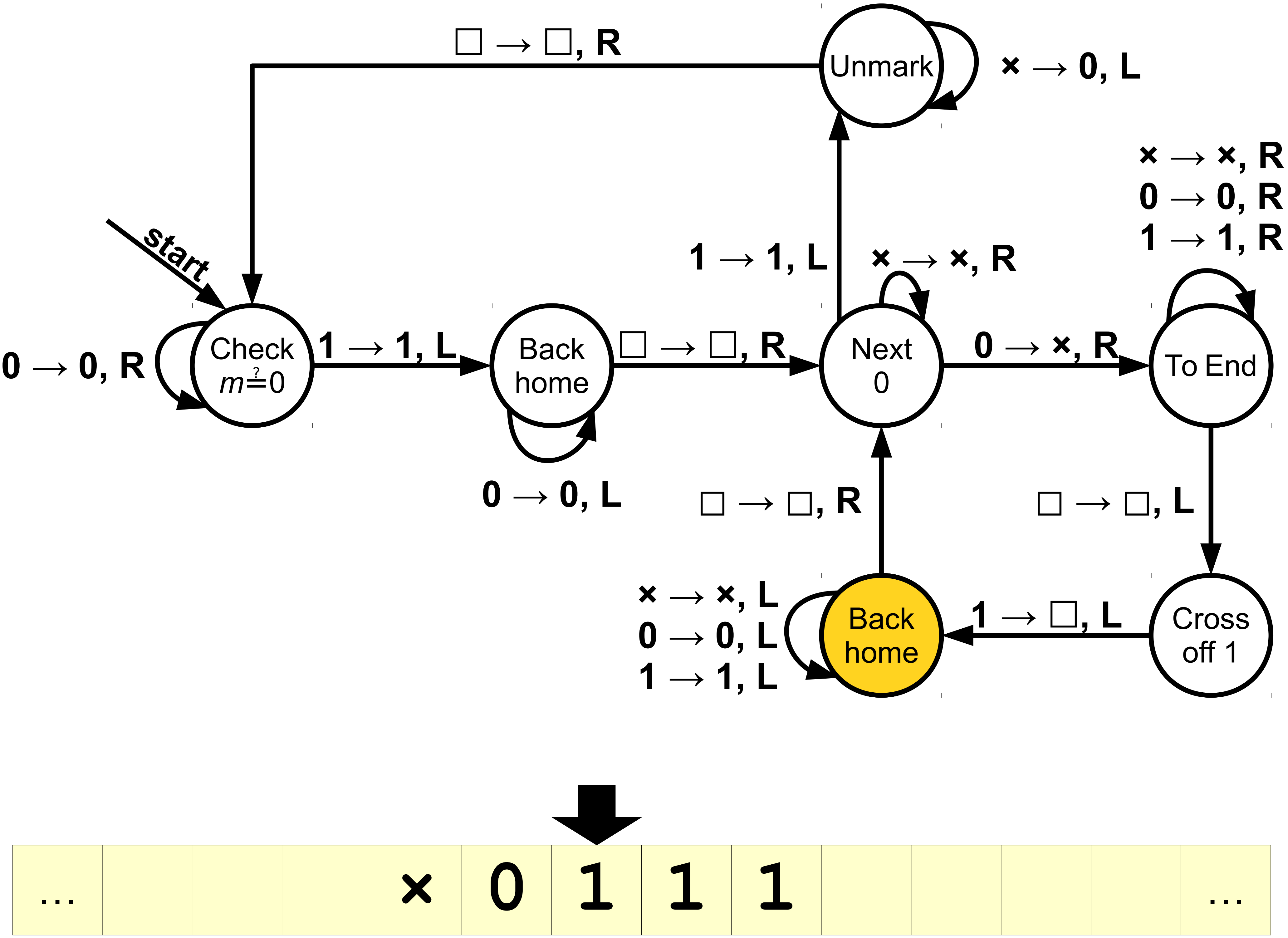

start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
1 → 1, L
× → ×, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
Unmark
× → 0, L
□ → □, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
0
1
1
1
1
…

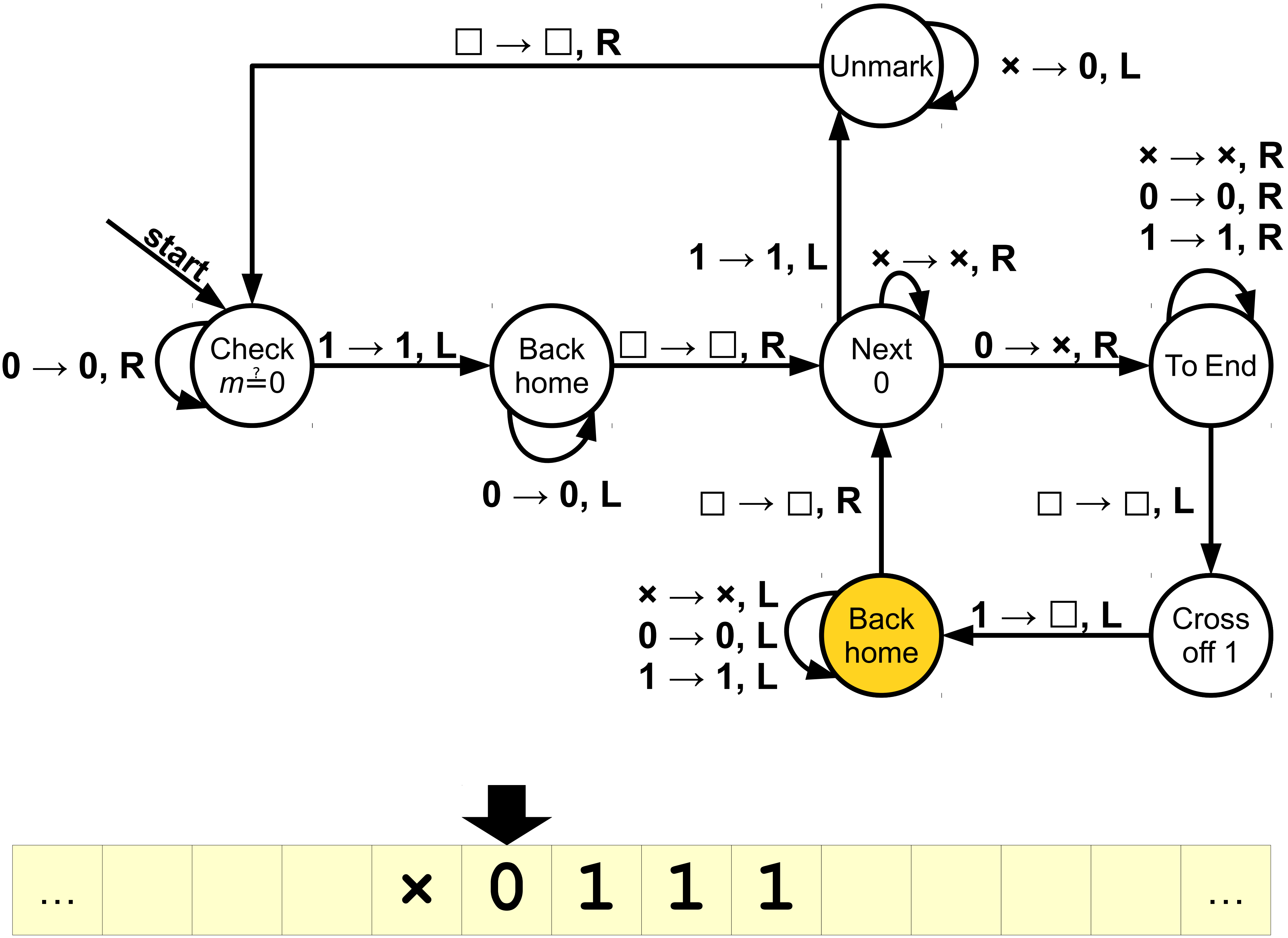


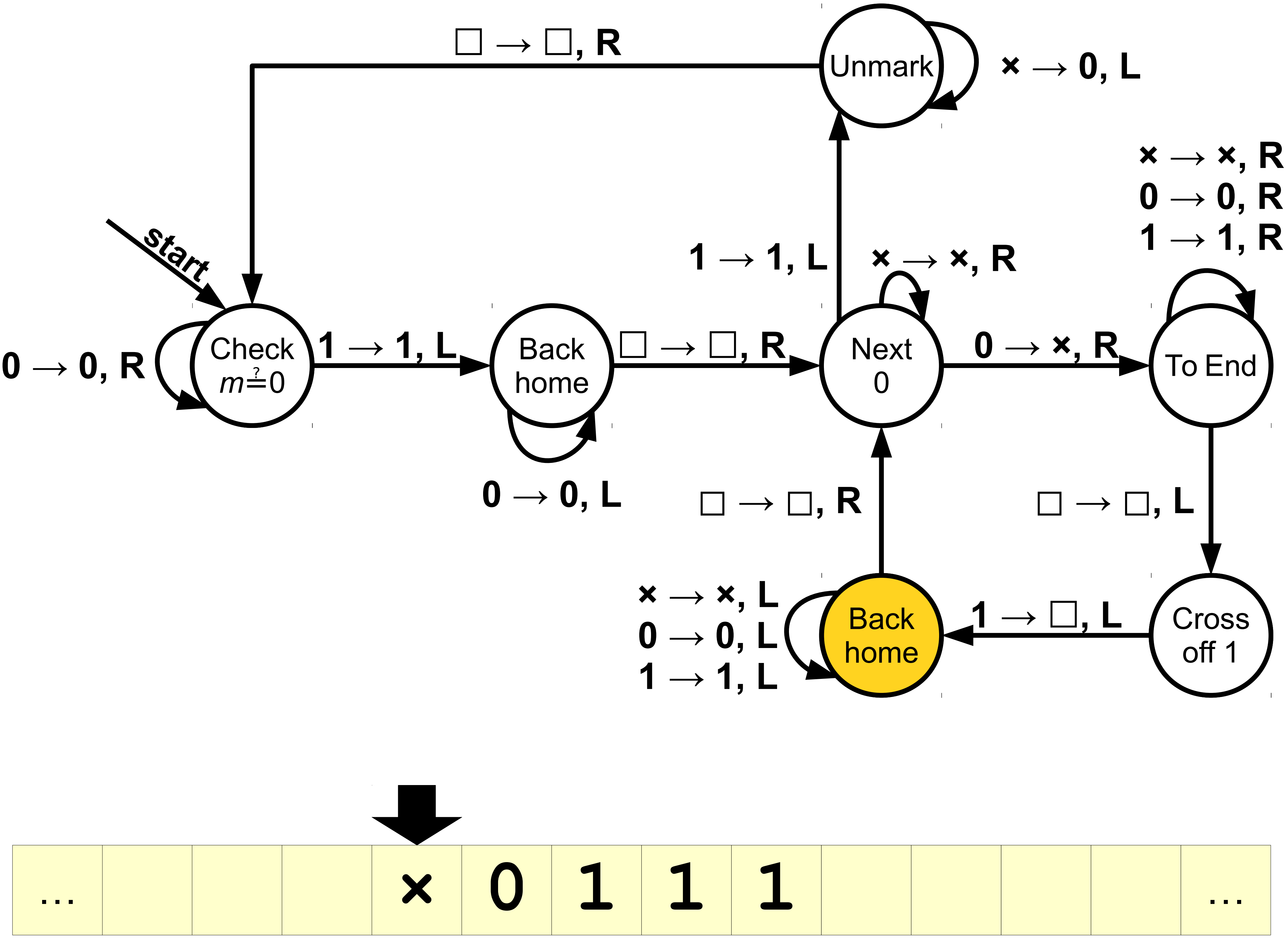
start
Check
$m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
1 → 1, L
× → ×, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
Unmark
× → 0, L
□ → □, R
…
×
0
1
1
1
1
…

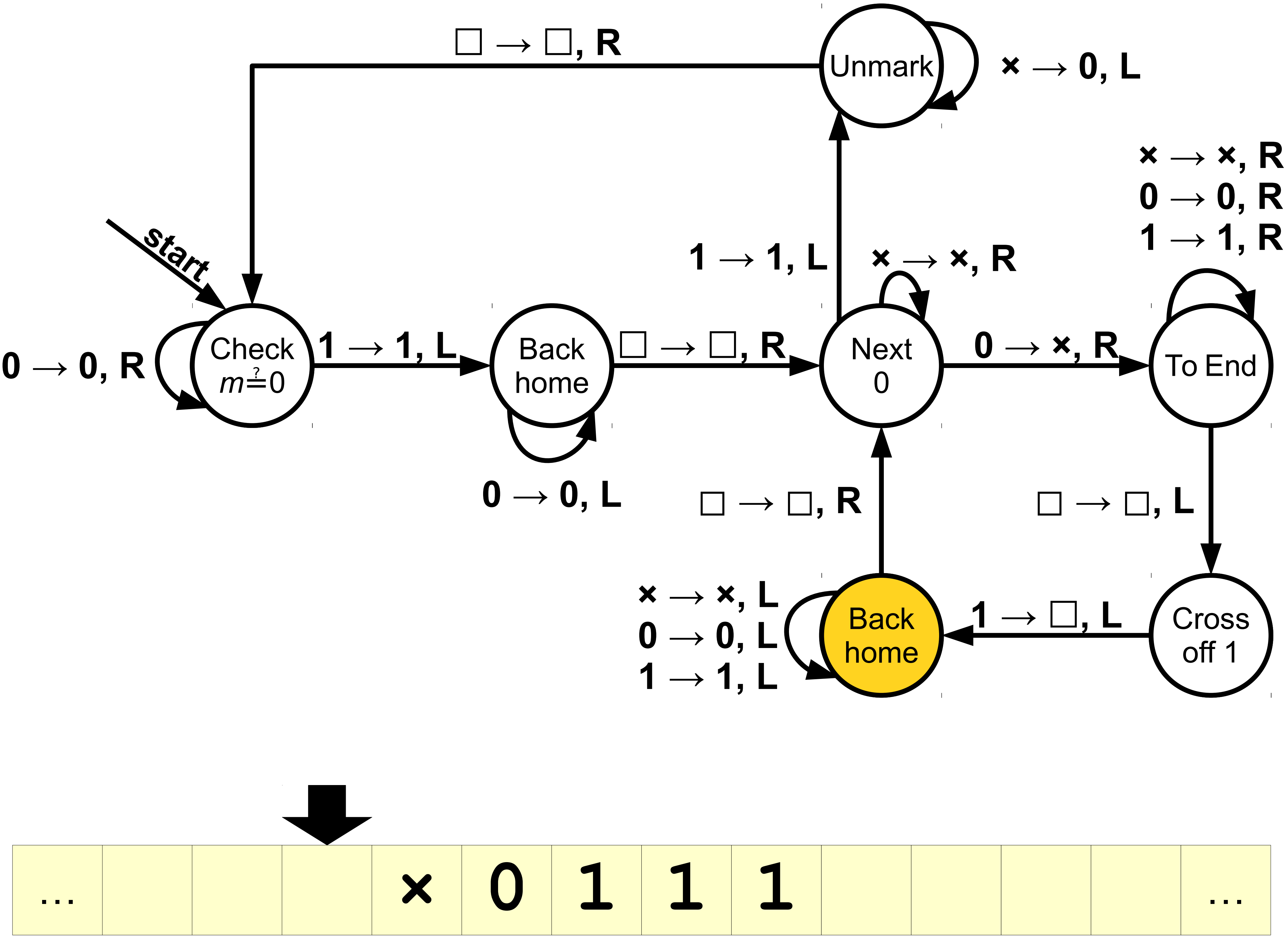

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
start
1 → 1, L
× → ×, R
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
1
1
1
…

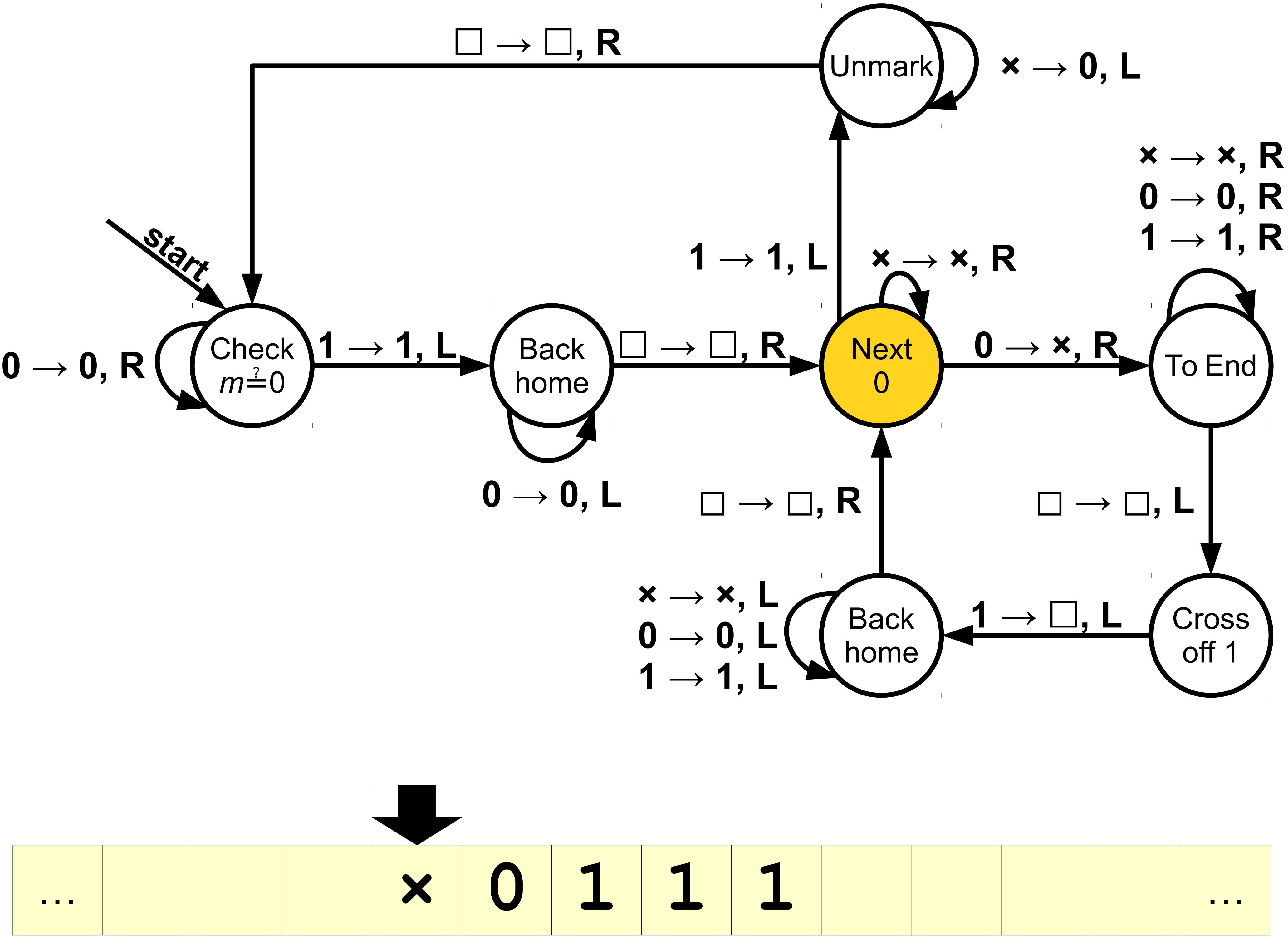

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
m≟0
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
1
1
1
…

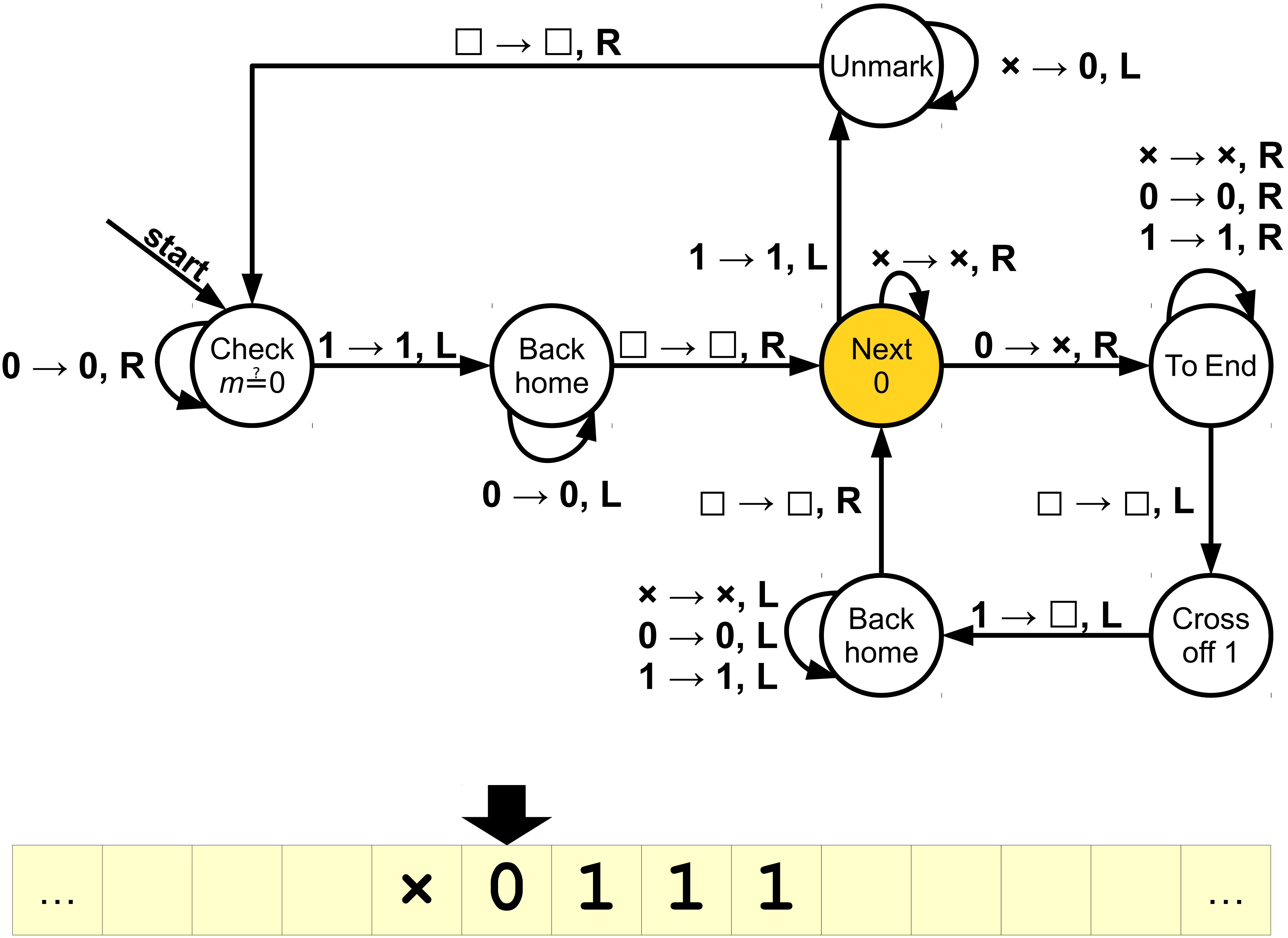

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
start
1 → 1, L
× → ×, R
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
1
1
1
…

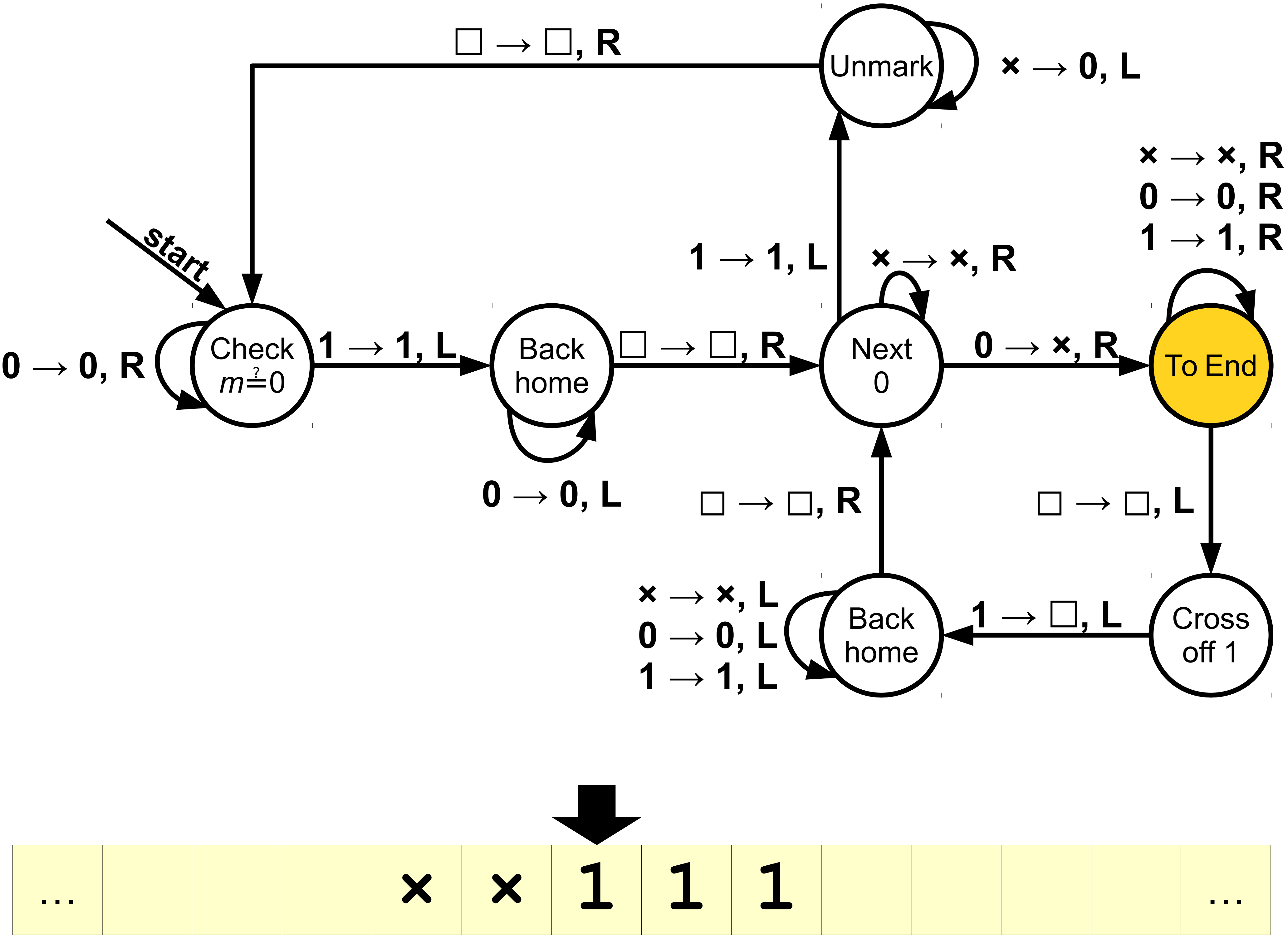

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
1
1
1
…

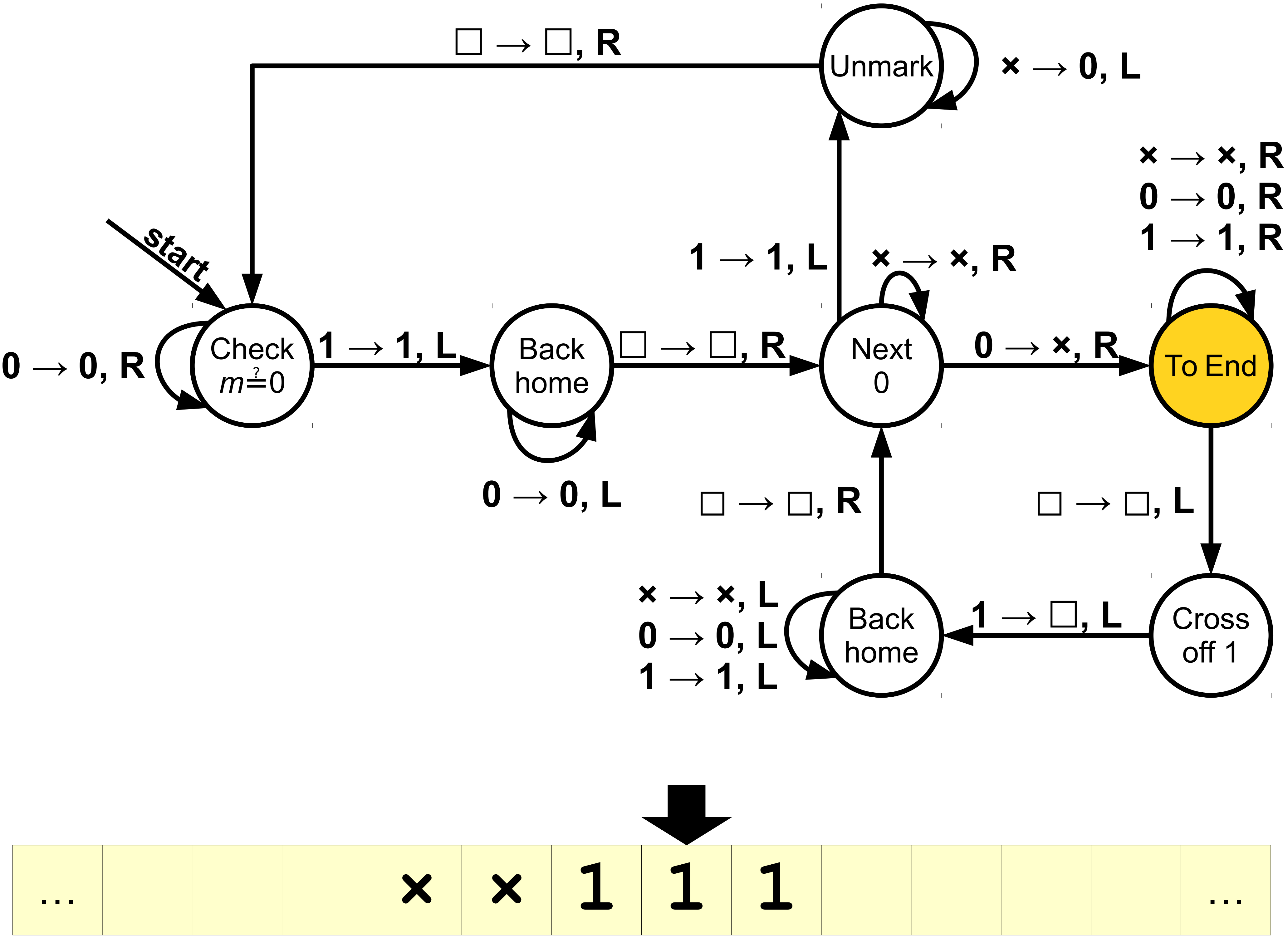

□ → □, R
Unmark
× → 0, L
start
Check $m \stackrel{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
1 → 1, L
× → ×, R
Next 0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back home
1 → □, L
Cross off 1
…
×
0
1
1
1
…

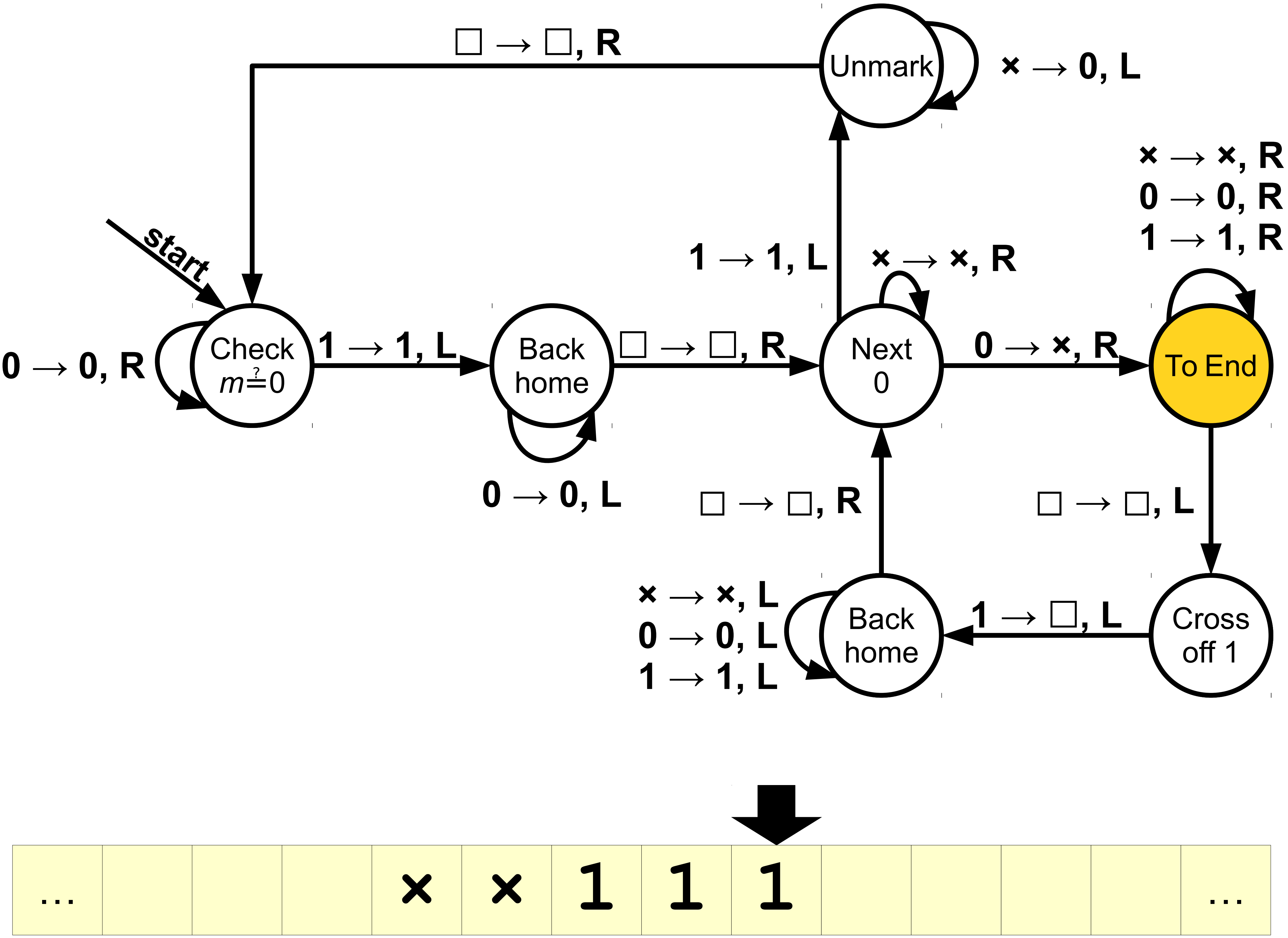

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
1
1
1
…

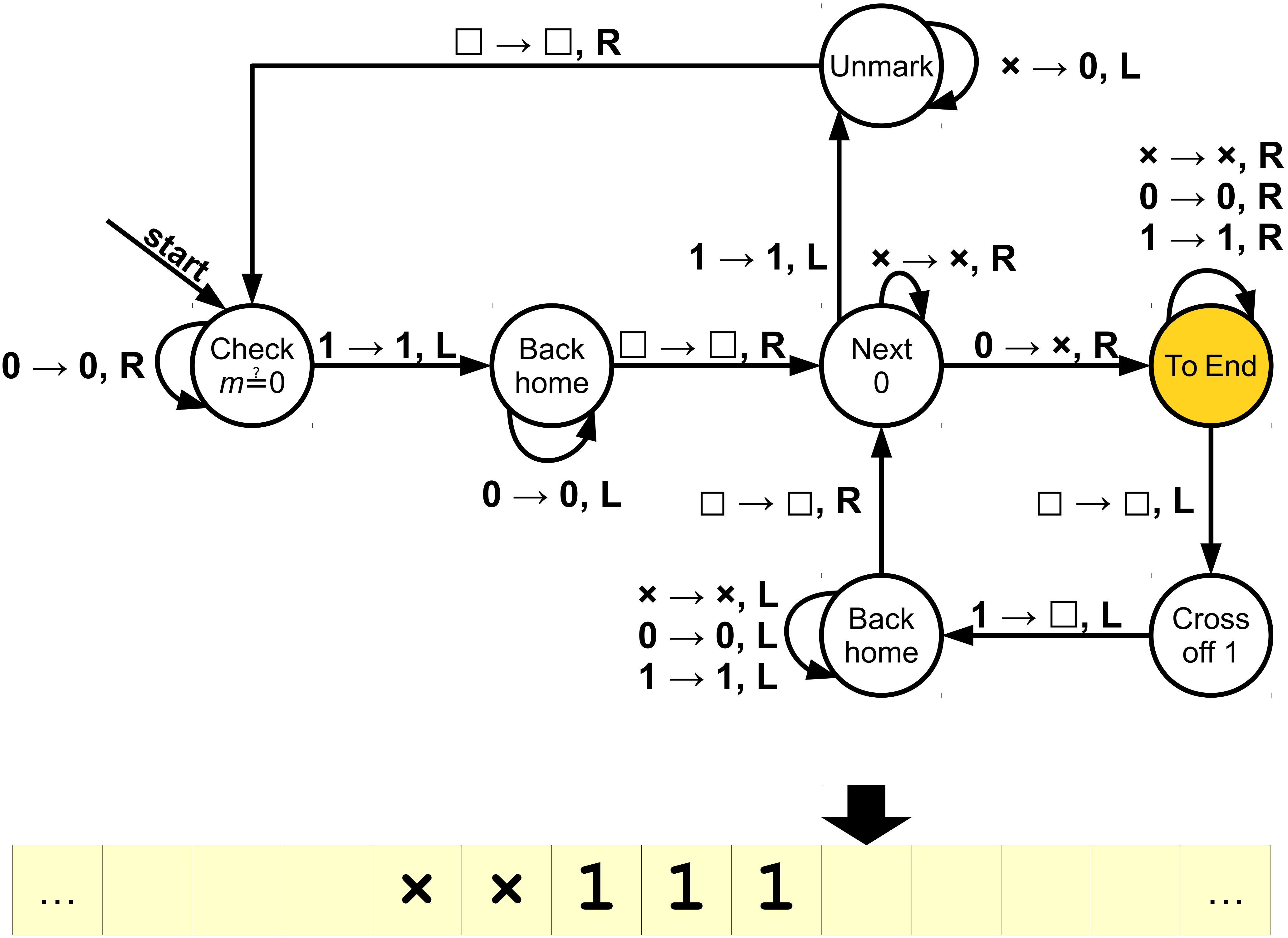

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
1
1
1
…

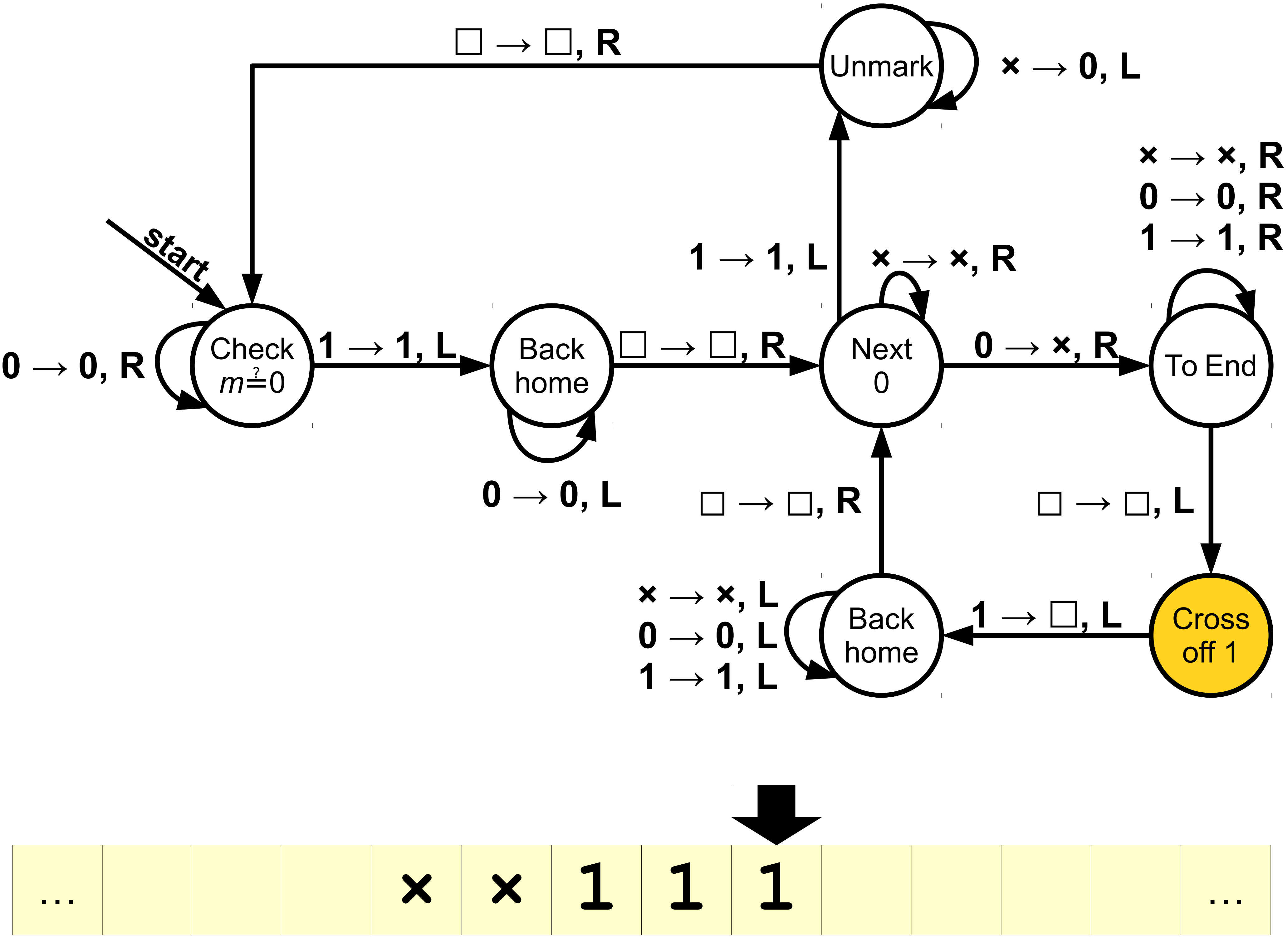

start
Check
m ≟ 0
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next
0
× → ×, R
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
0
1
1
1
…

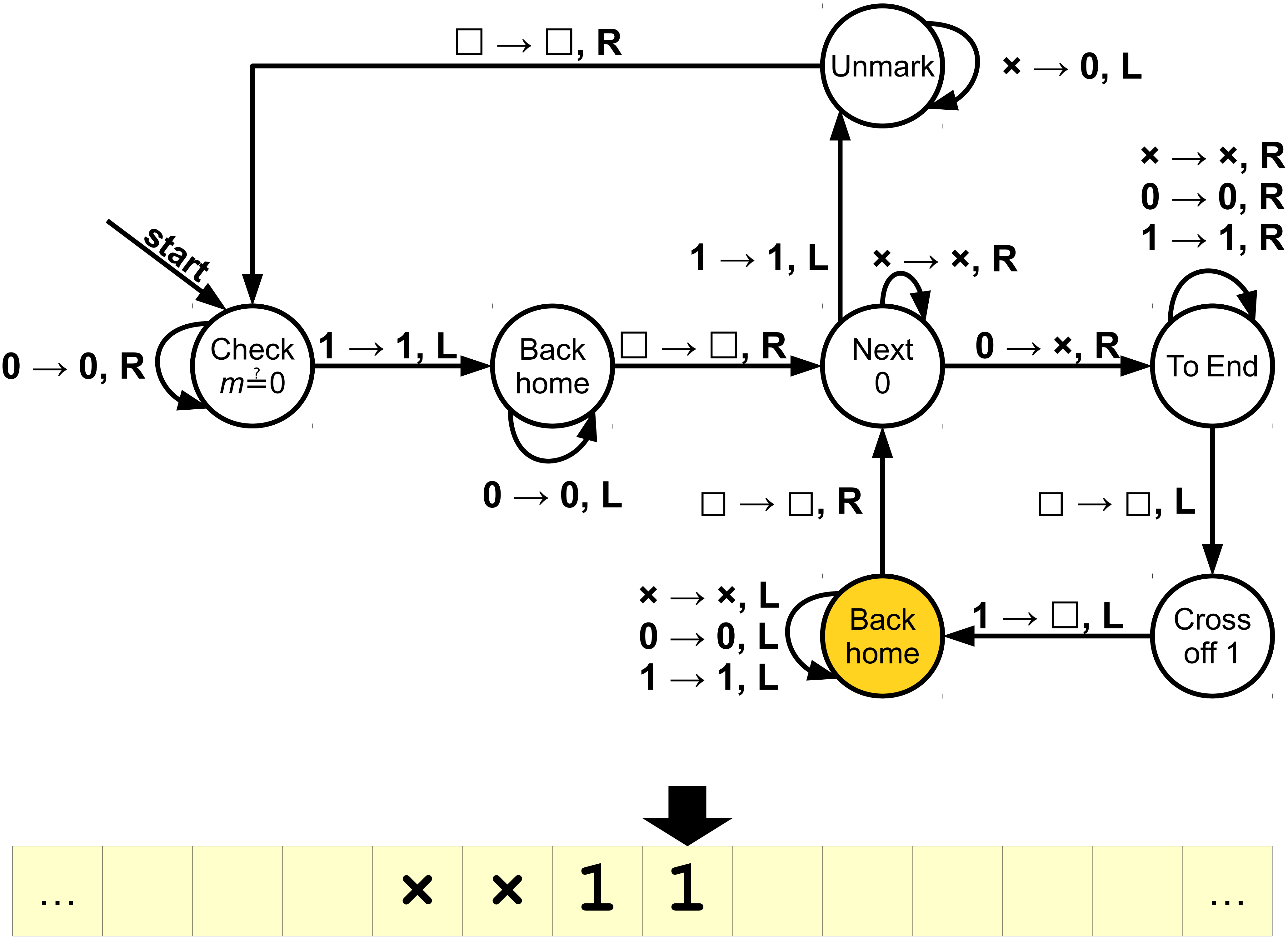

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
m≟0
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
×
1
1
1
…

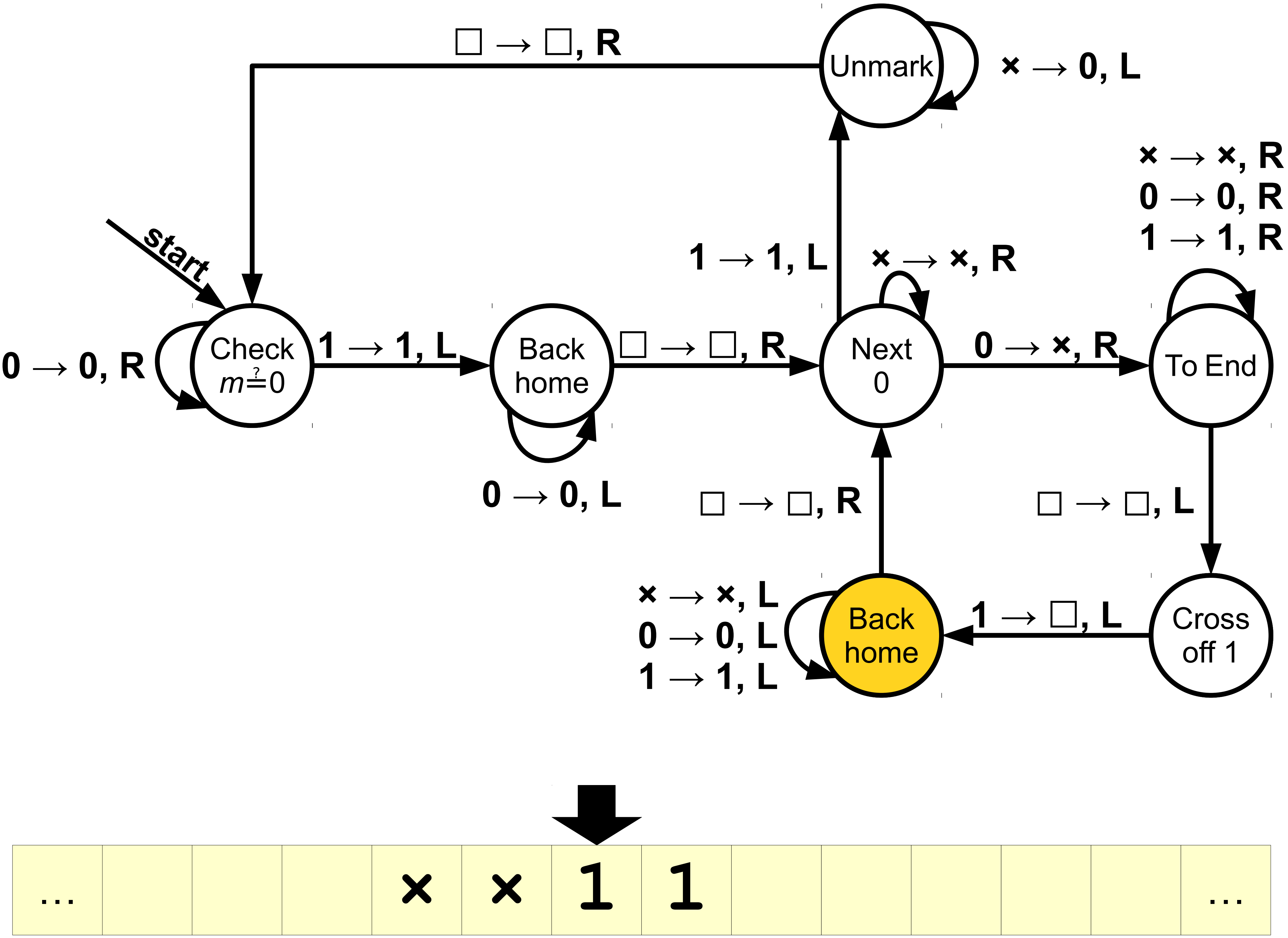

start
Check $m \stackrel{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
1
1
1
…

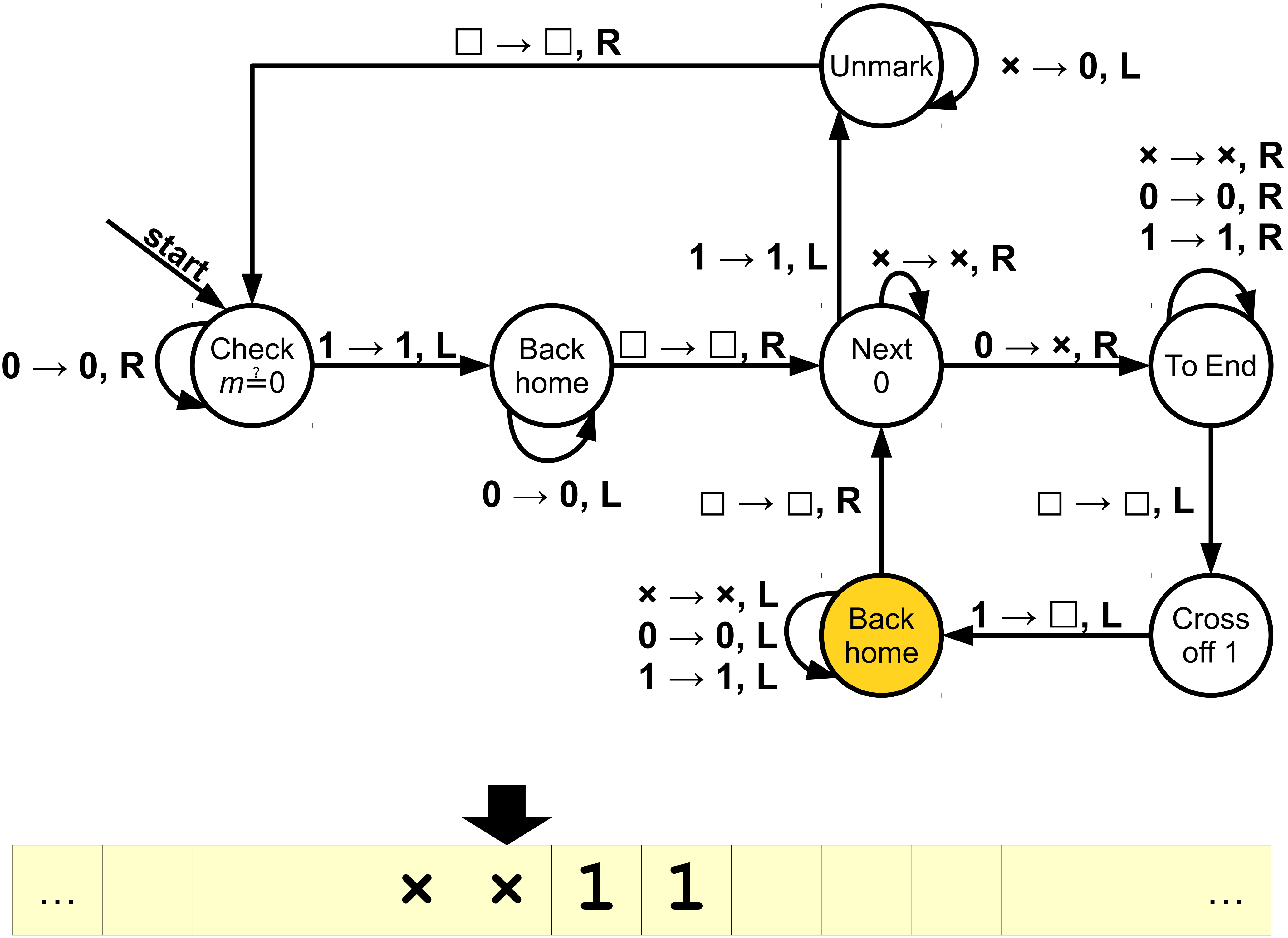

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
start
1 → 1, L
× → ×, R
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
×
1
1
1
…

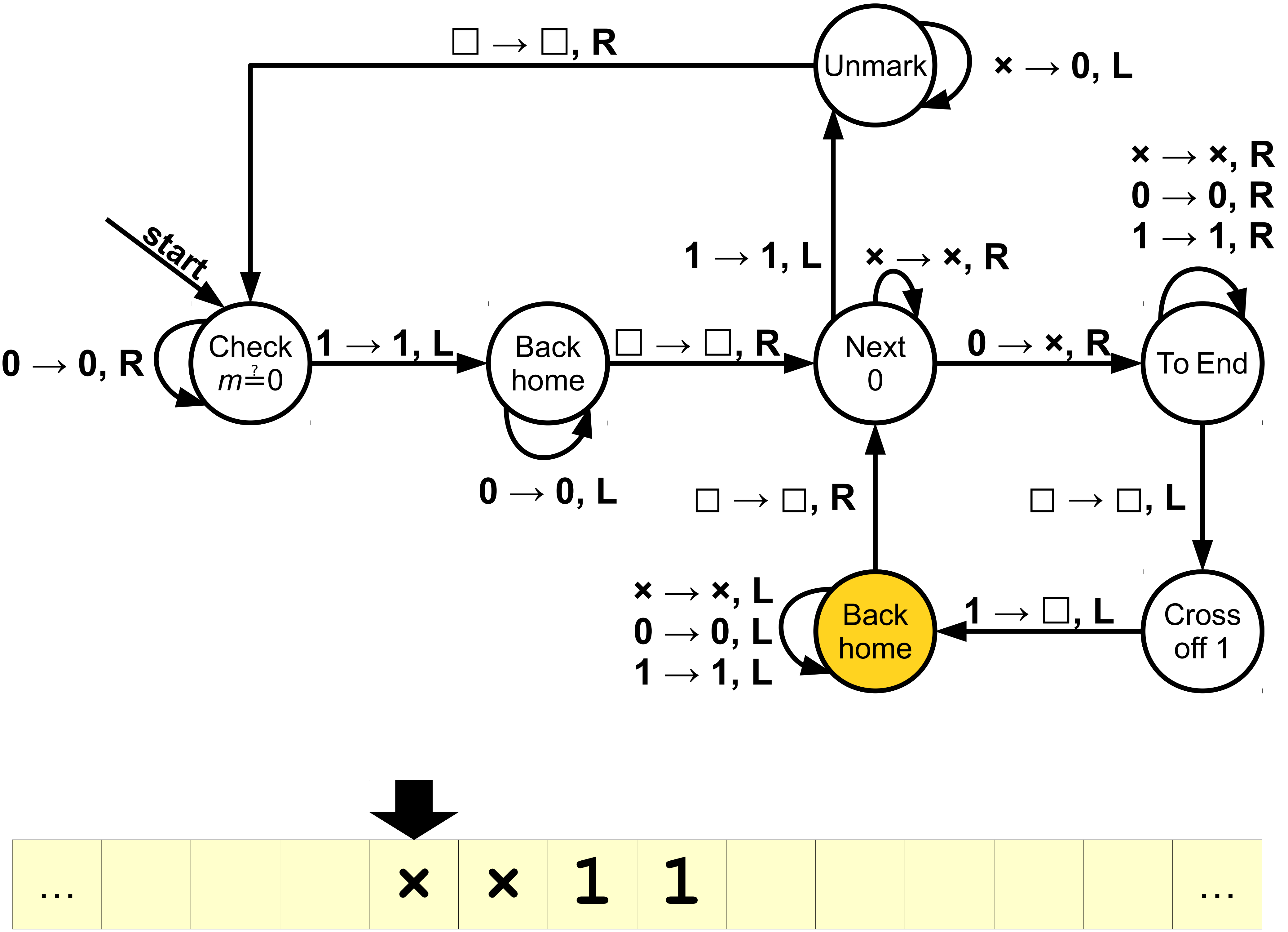

start
Check $m \stackrel{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
1
1
1
…

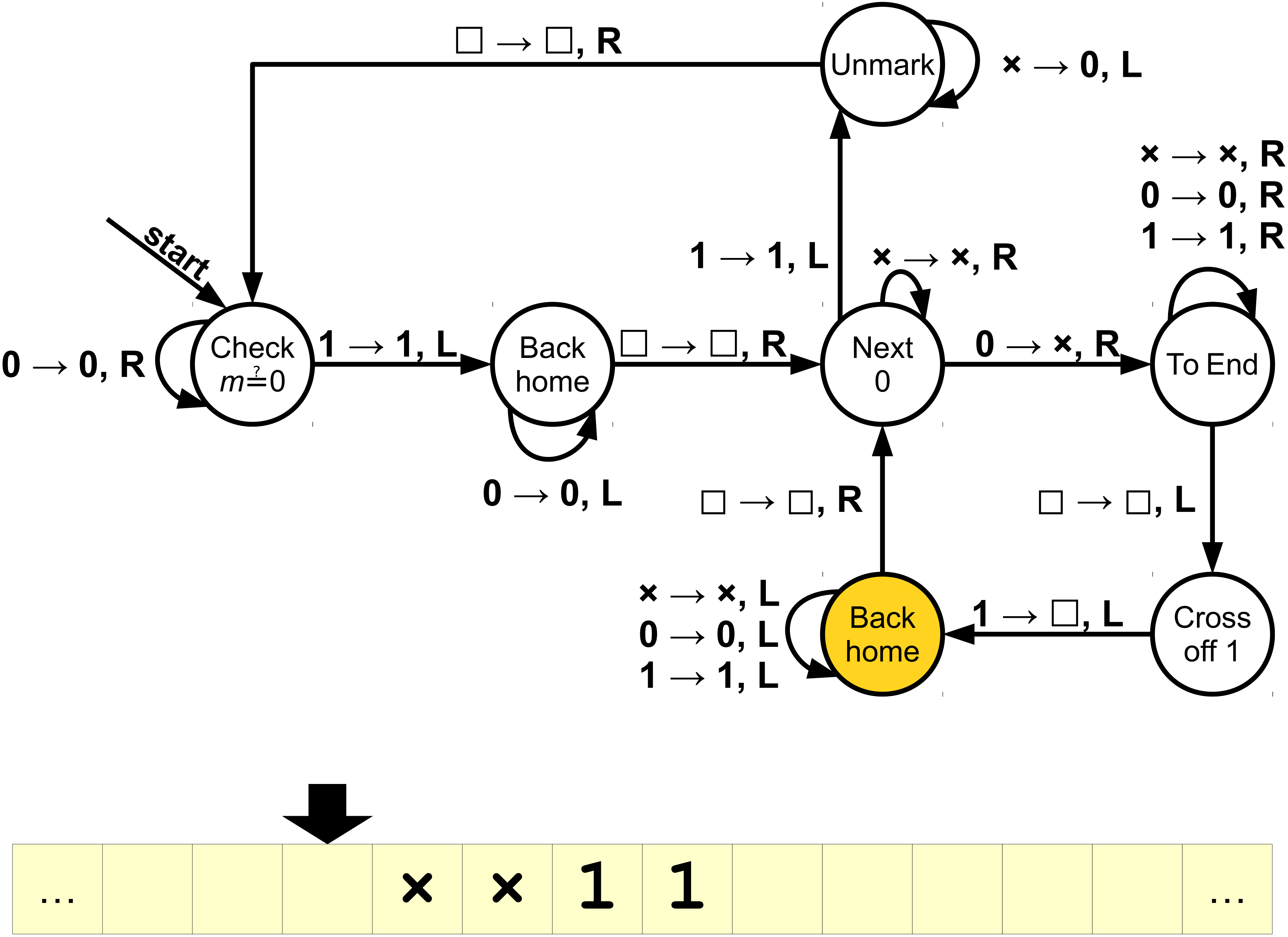

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
×
1
1
1
…

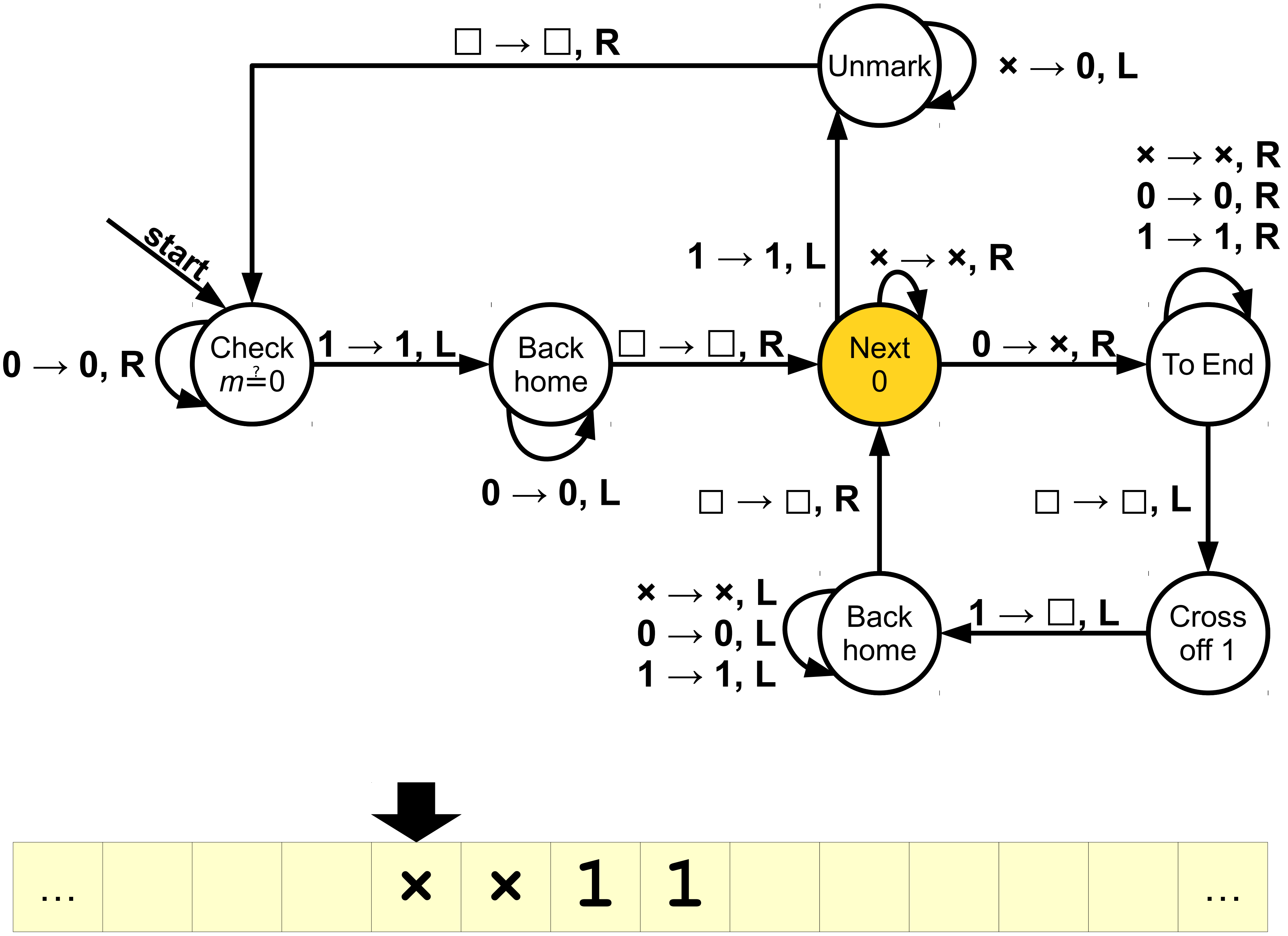

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
×
1
1
…

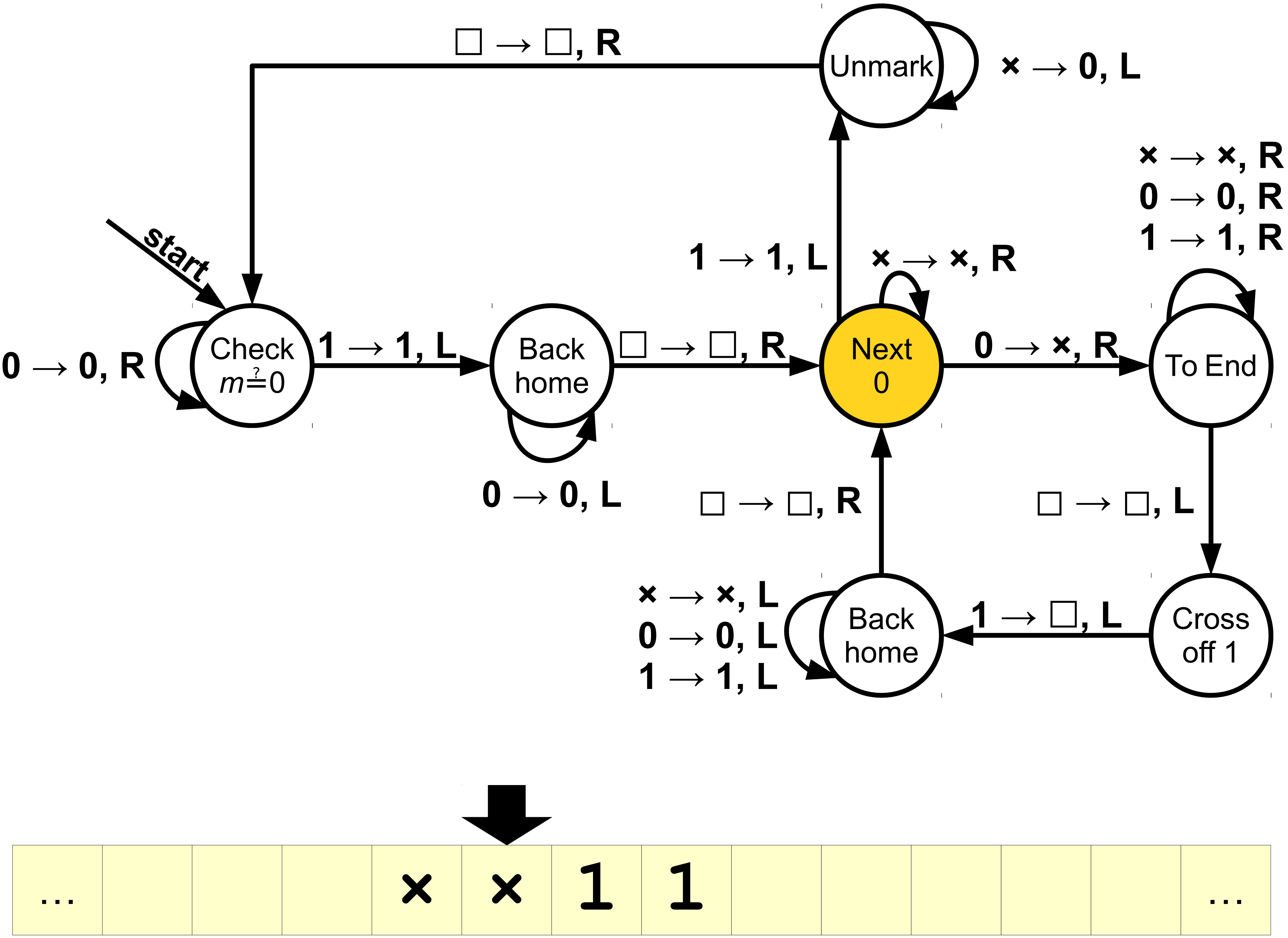

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
m ≟ 0
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
×
1
1
…

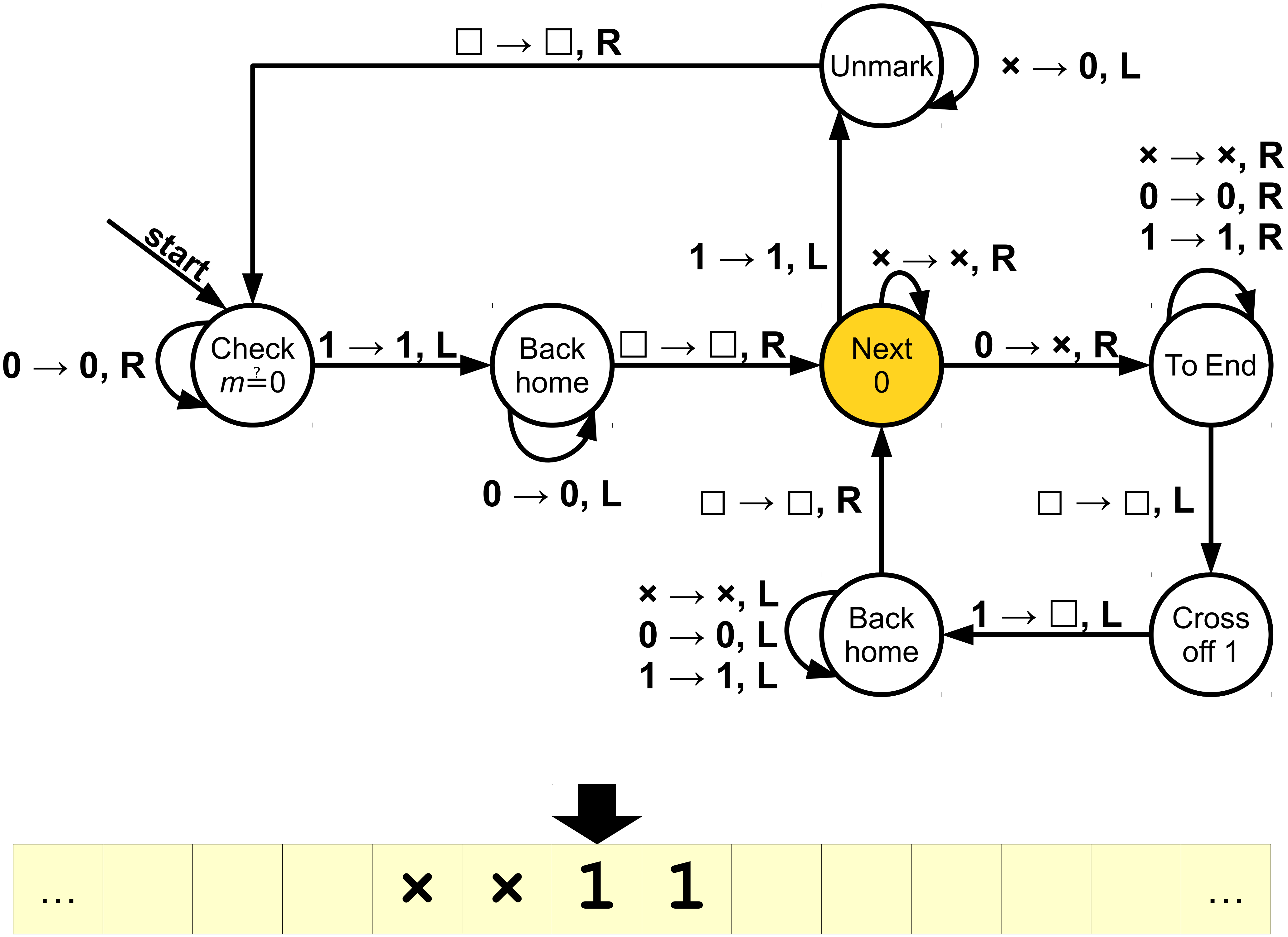

start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
1 → 1, L
× → ×, R
0 → ×, R
Unmark
× → 0, L
□ → □, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
1
1
…

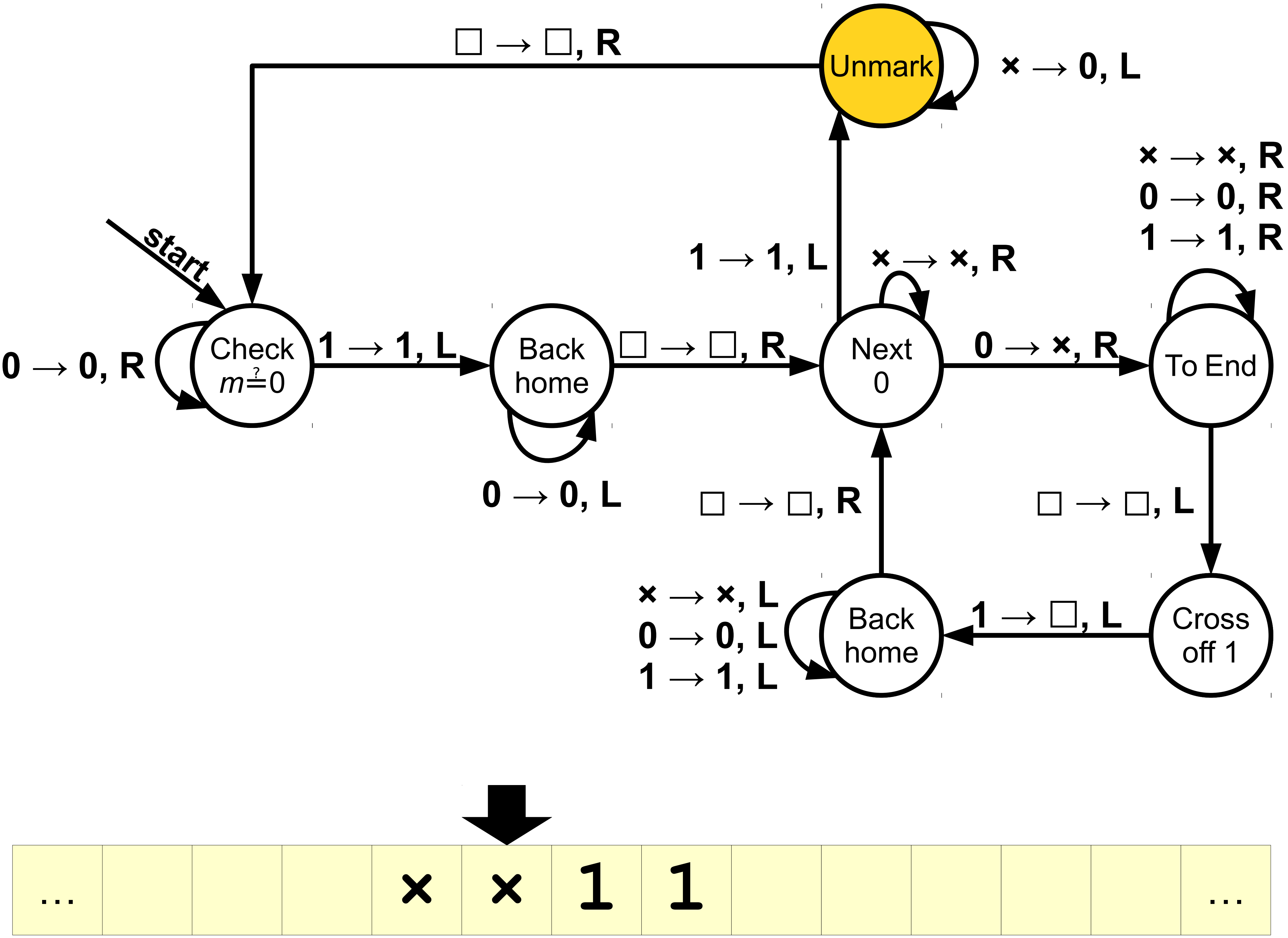

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
start
1 → 1, L
× → ×, R
0 → 0, R
Check
m≟0
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
×
1
1
…


□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
start
1 → 1, L
× → ×, R
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
×
1
1
…

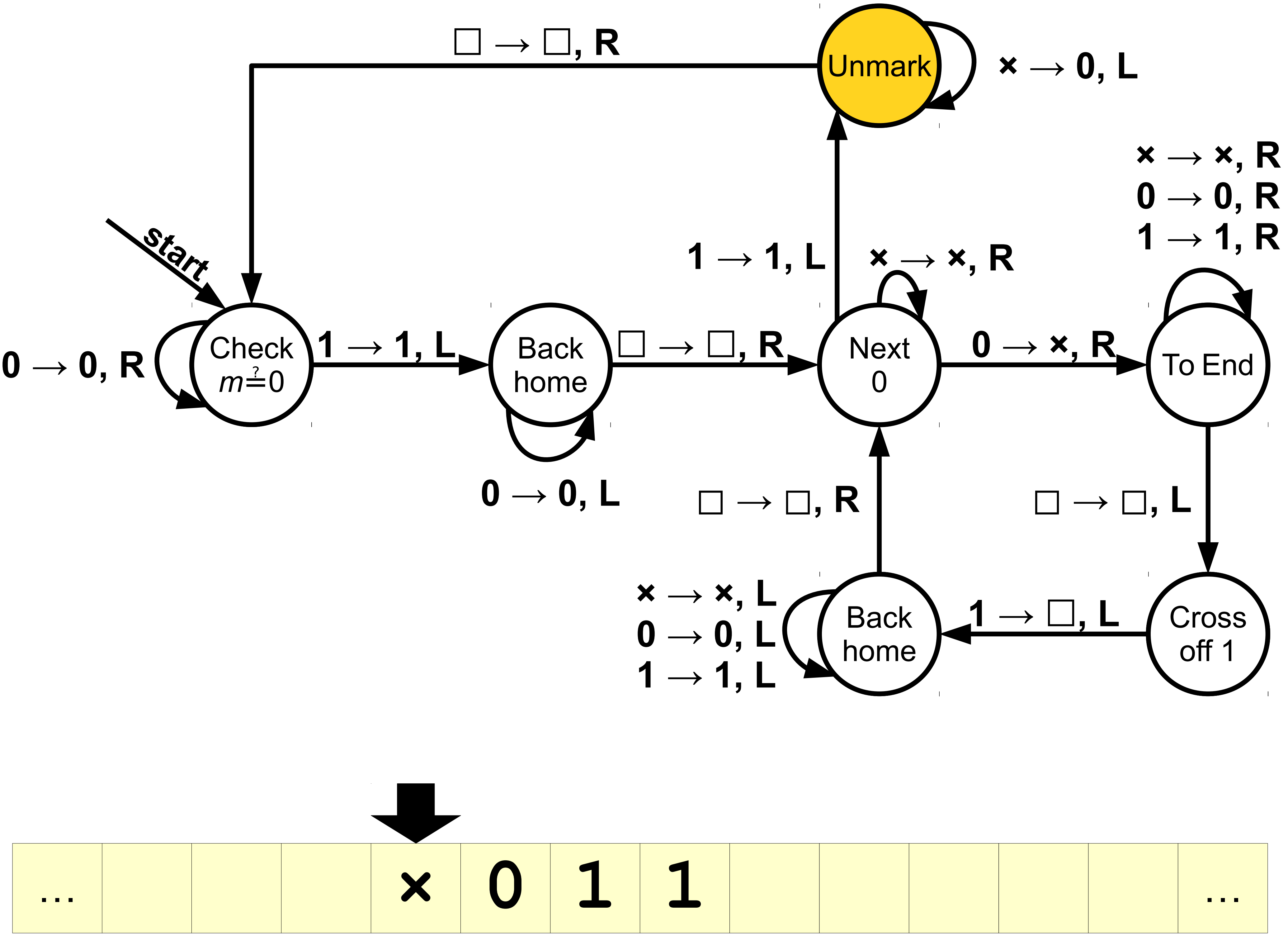

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
×
1
1
…

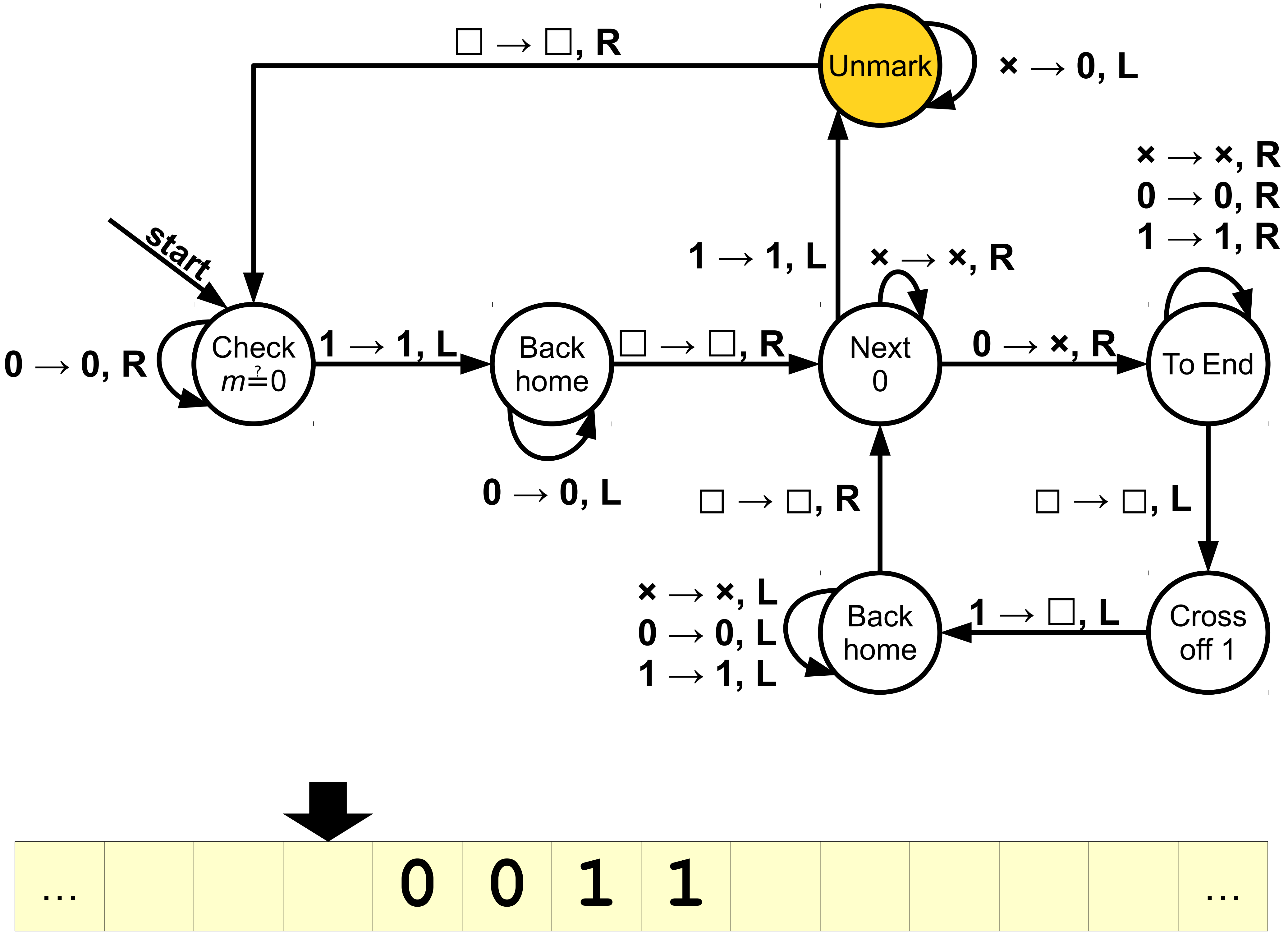

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
Check
$m \stackrel{?}{=} 0$
0 → 0, R
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
×
1
1
…

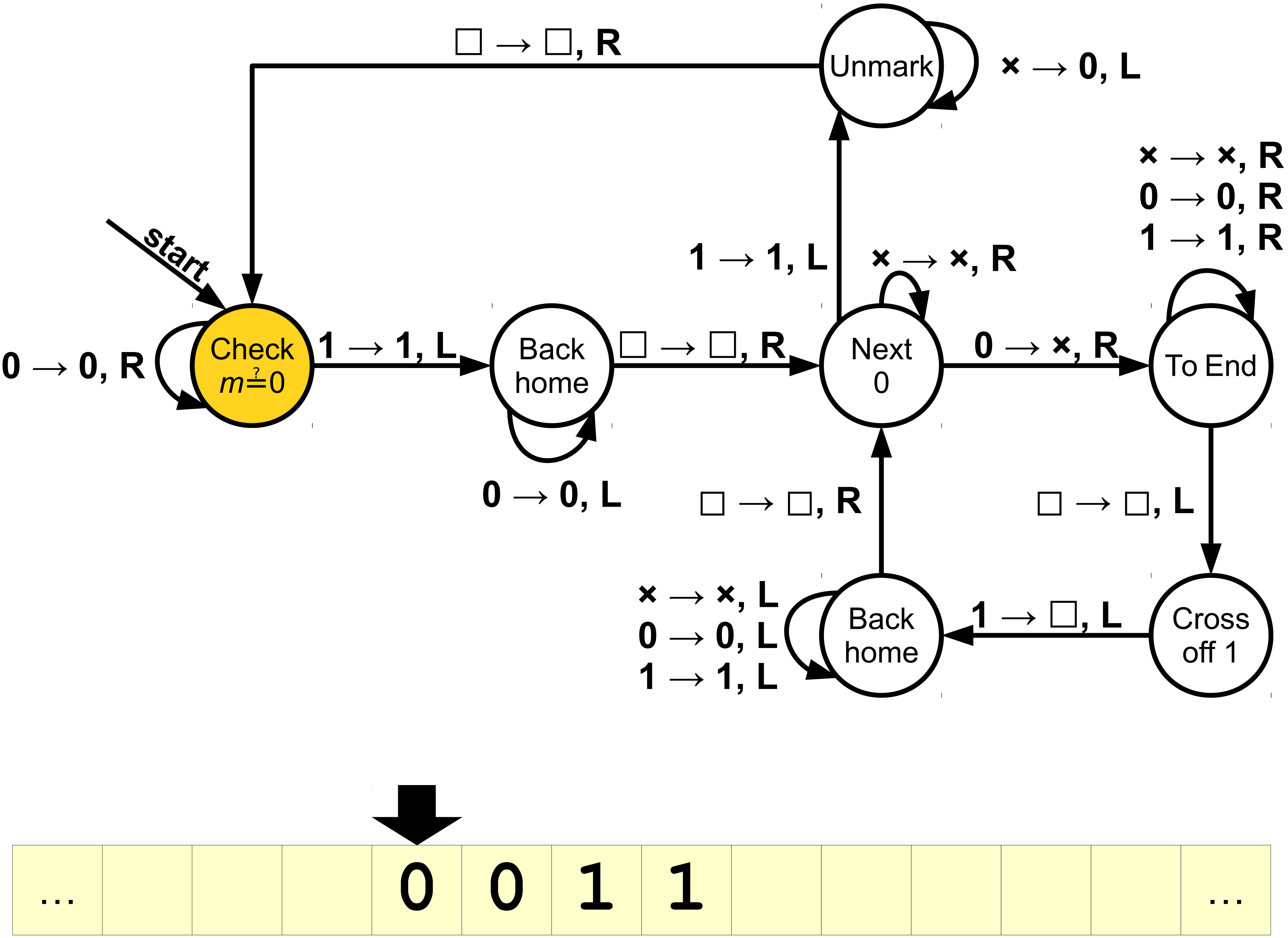

□ → □, R
Unmark
× → 0, L
start
Check
$m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
1 → 1, L
× → ×, R
Next
0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, L
□ → □, R
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
…
×
×
1
1
…

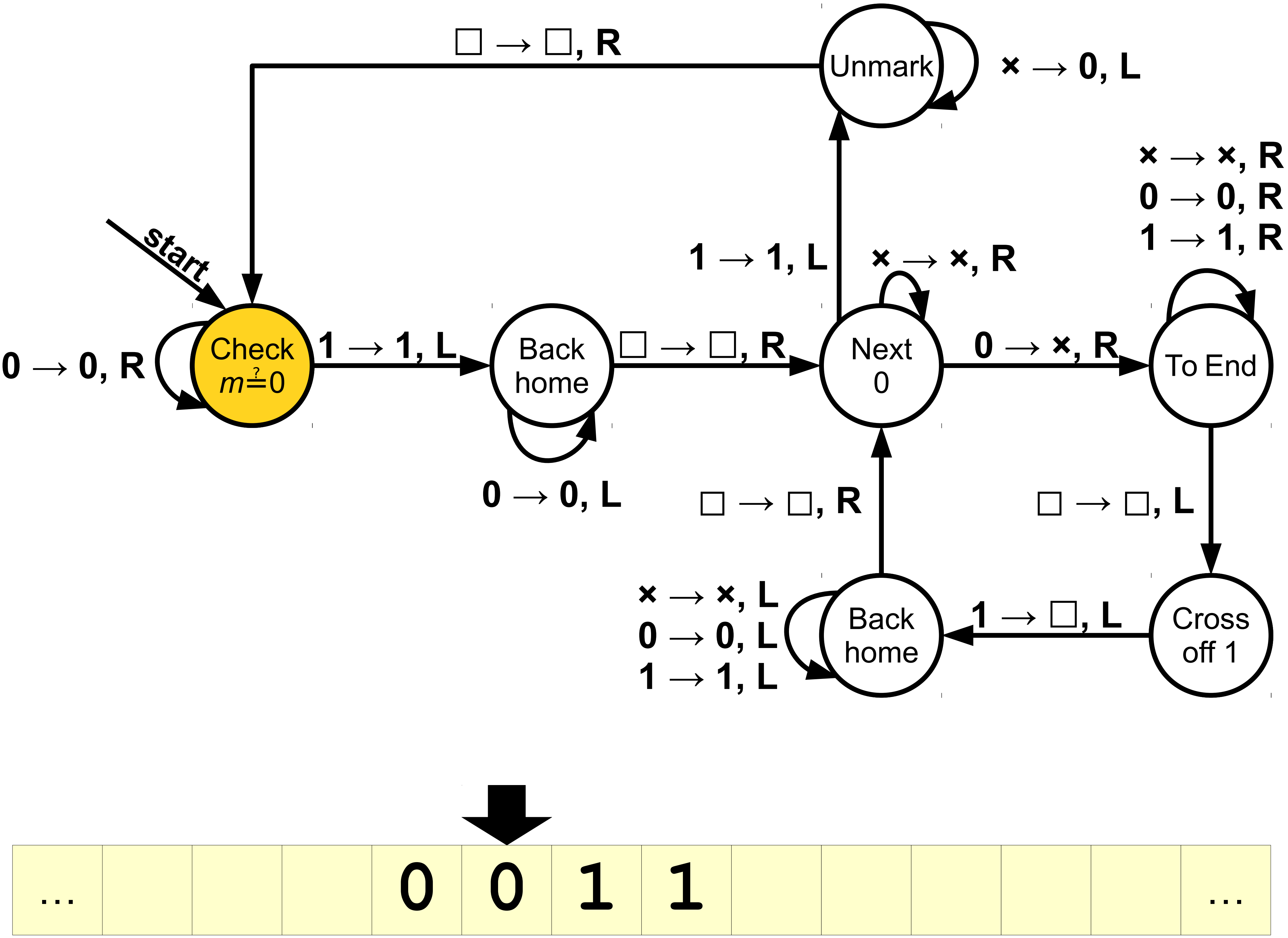


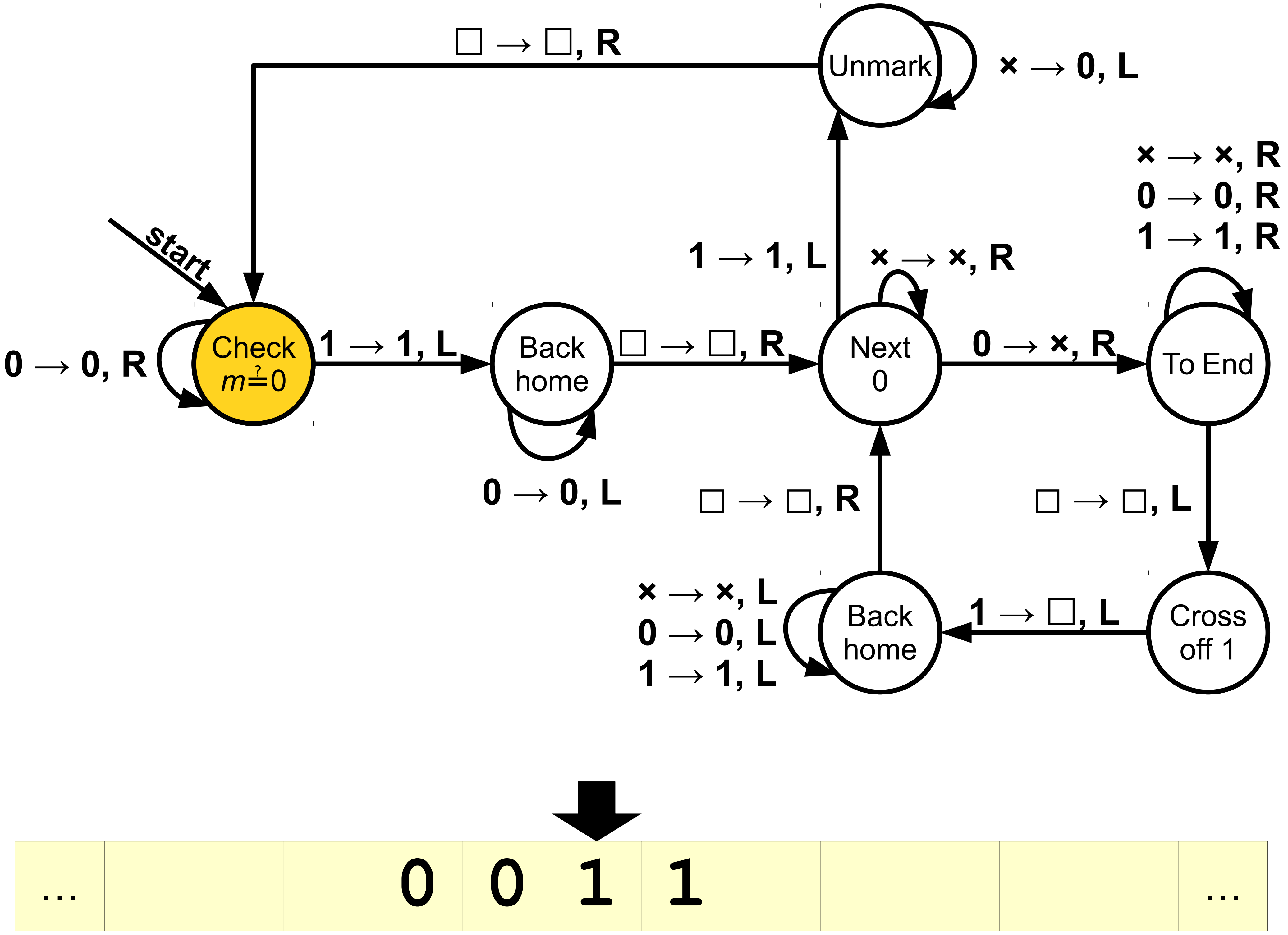
start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
1
1
…

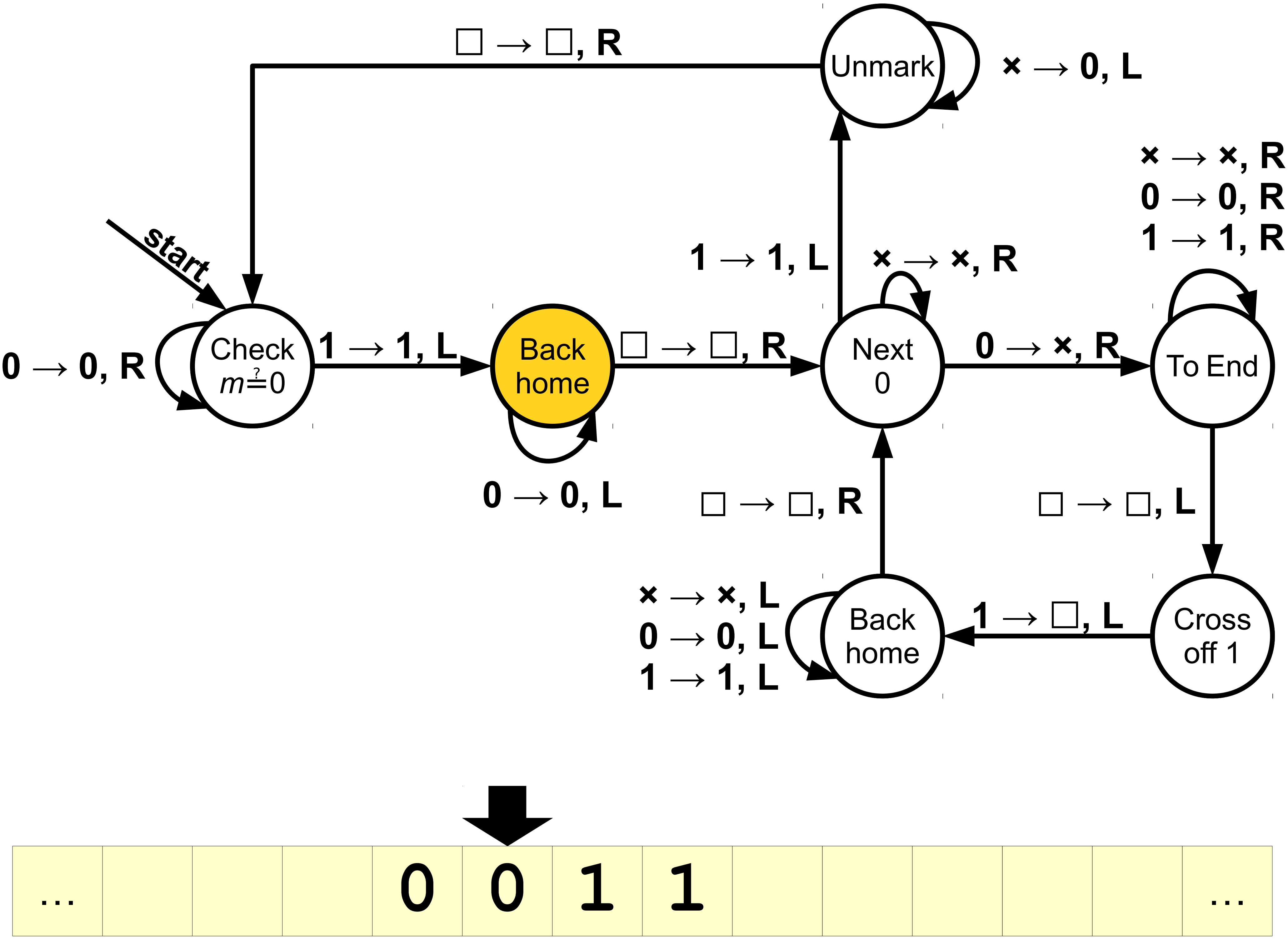

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
m≟0
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
1
1
…

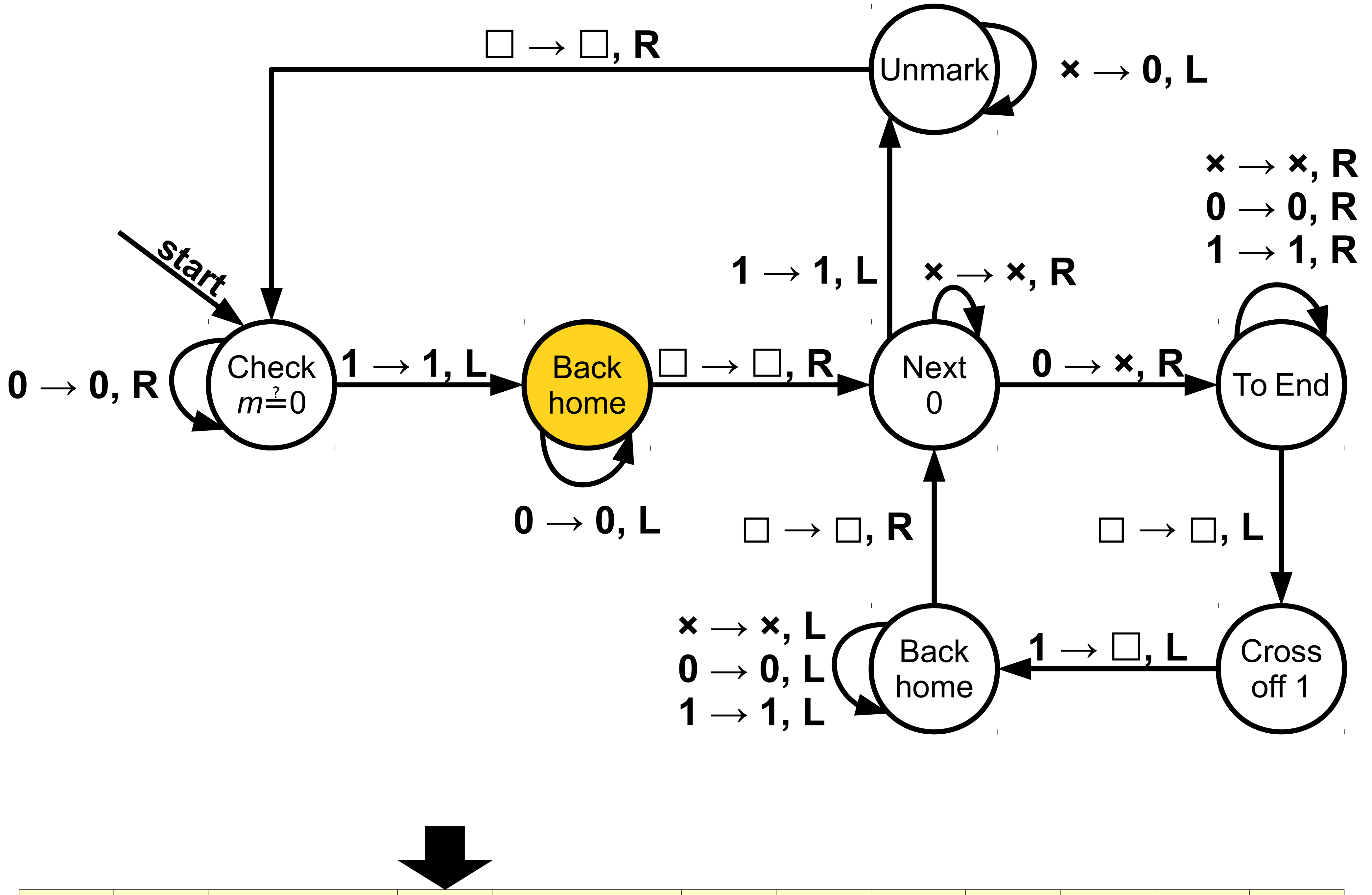

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
0
0
1
1
…


□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back home
□ → □, R
Next 0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back home
1 → □, L
Cross off 1
…
0
0
1
1
…

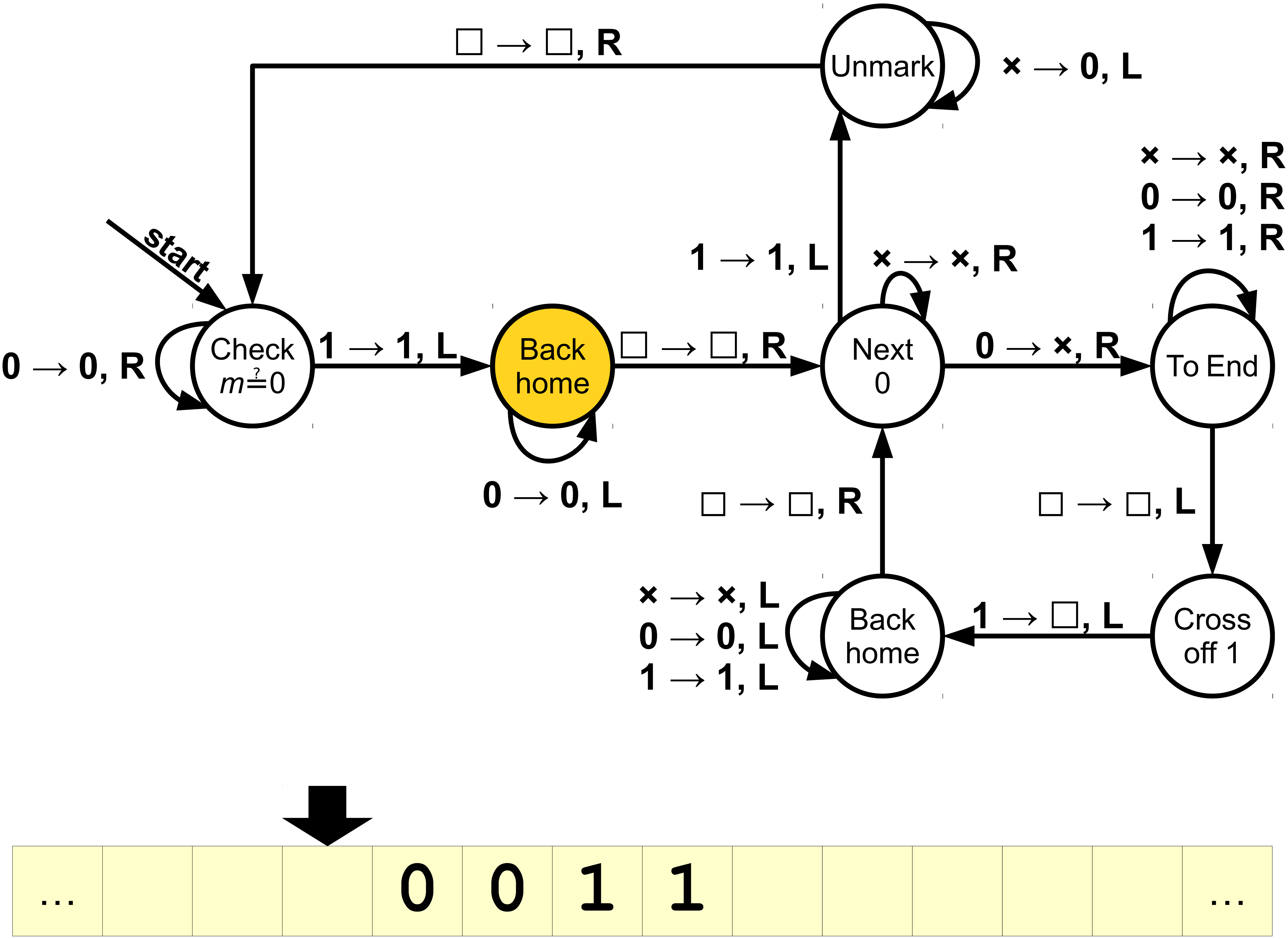

□ → □, R
Unmark
× → 0, L
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
0 → 0, L
□ → □, R
1 → 1, L
× → ×, R
Next
0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
0
0
1
1
…

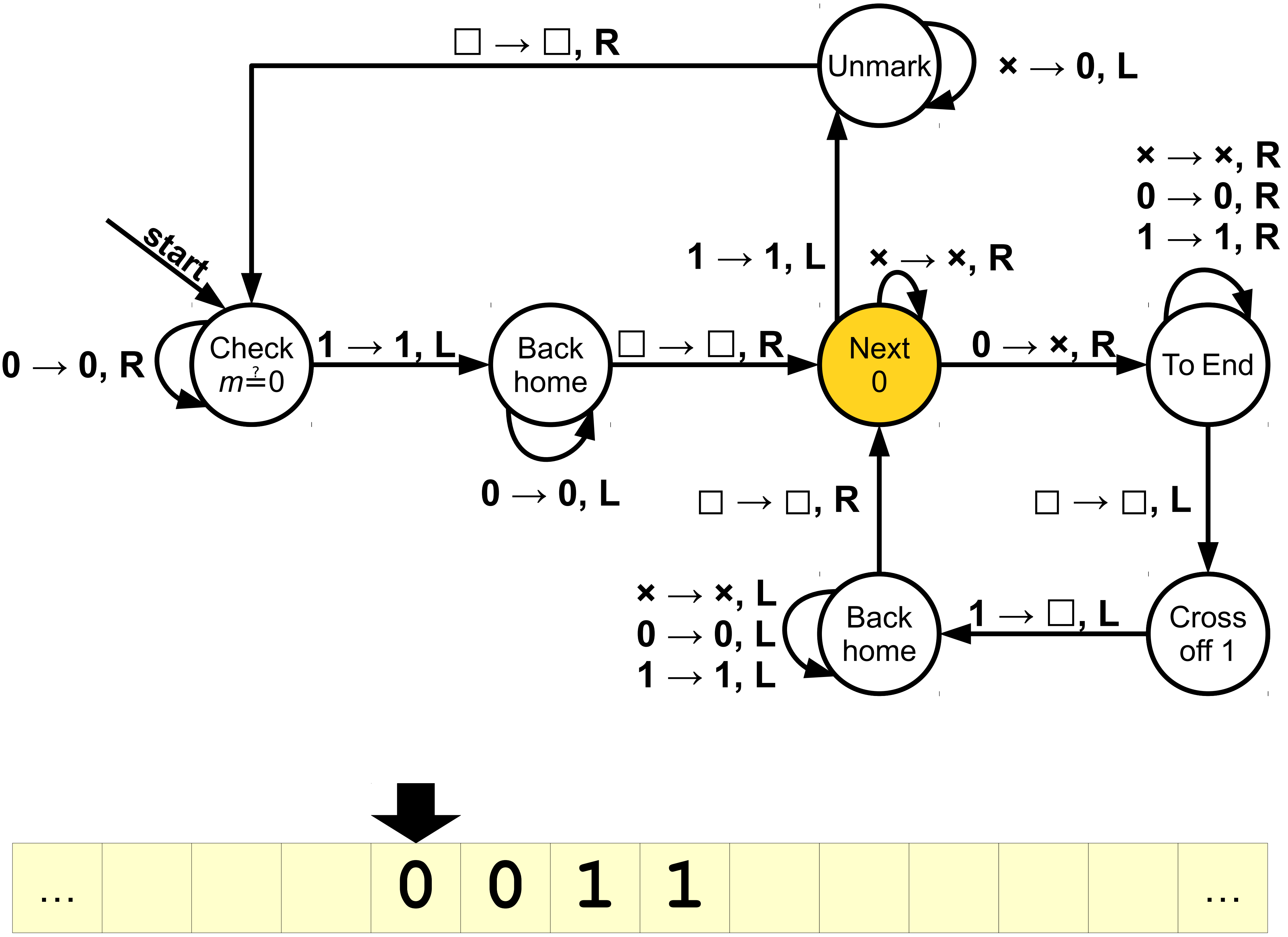

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
m ≟ 0
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
0
0
1
1
…

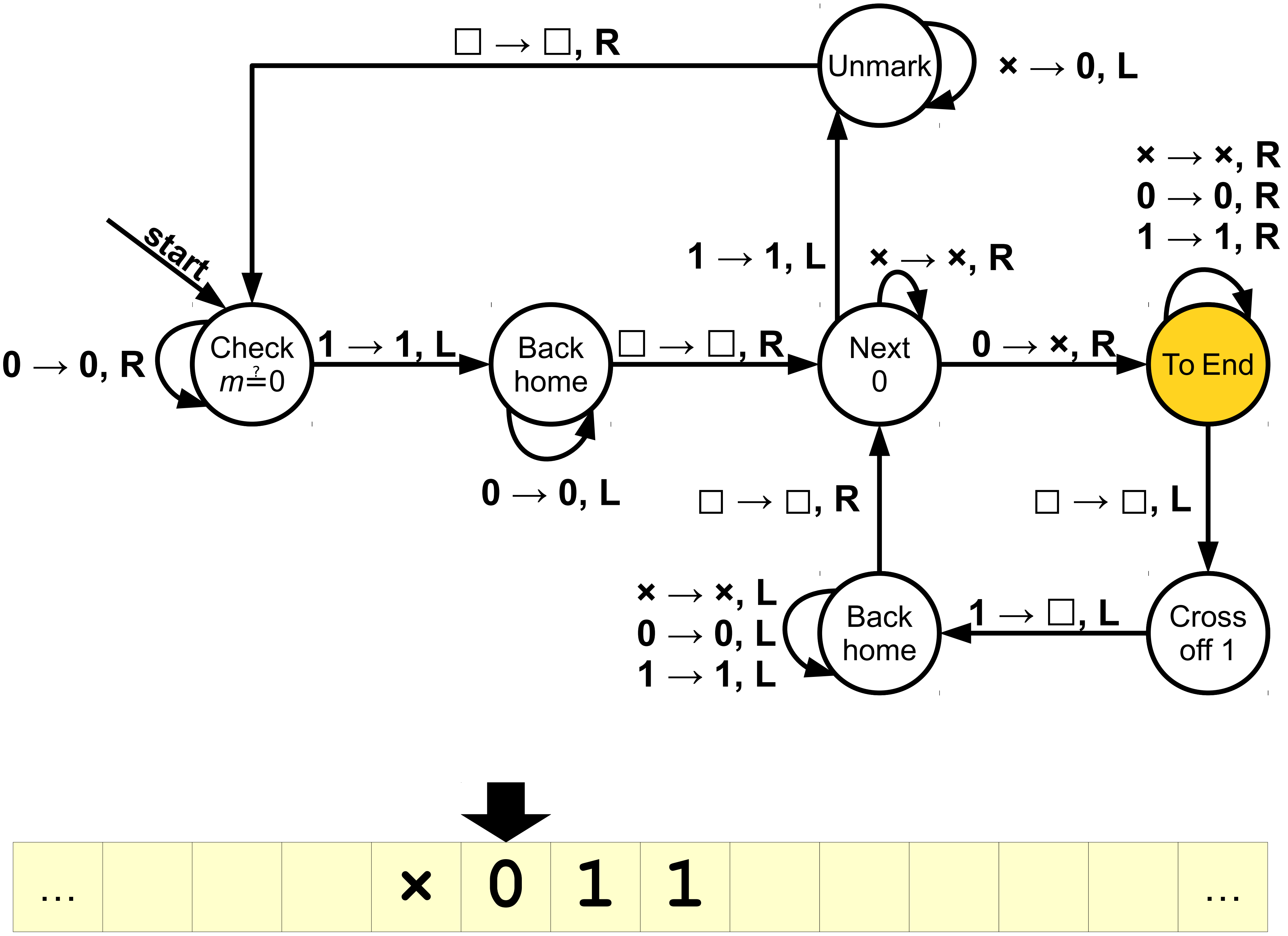

start
Check $m \stackrel{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
1 → 1, L
× → ×, R
0 → ×, R
Unmark
× → 0, L
□ → □, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
0
0
1
1
…

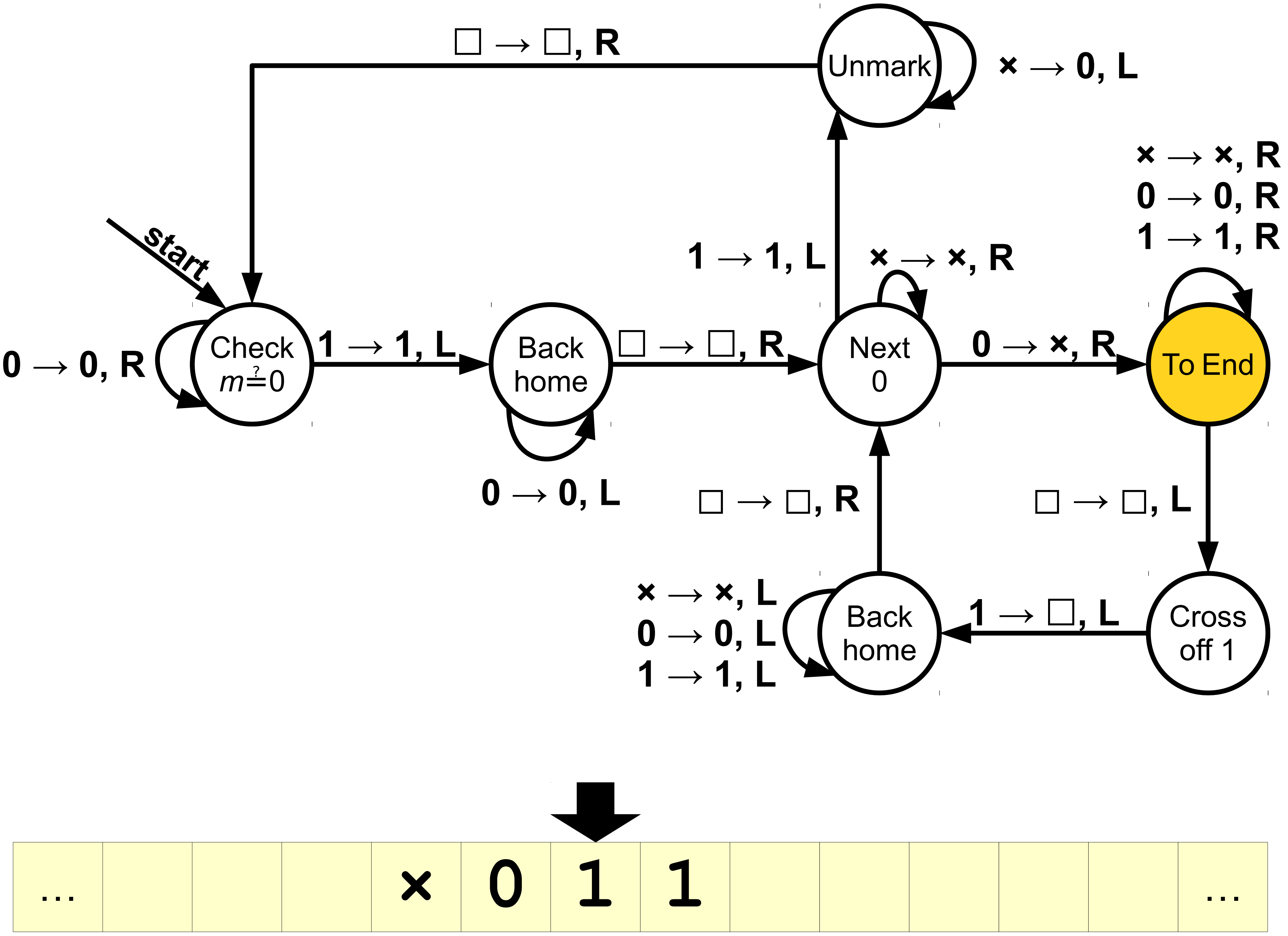

□ → □, R
Unmark
× → 0, L
start
Check
m≟0
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
1 → 1, L
× → ×, R
Next
0
0 → ×, R
× → ×, R
0 → 0, R
1 → 1, R
To End
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1

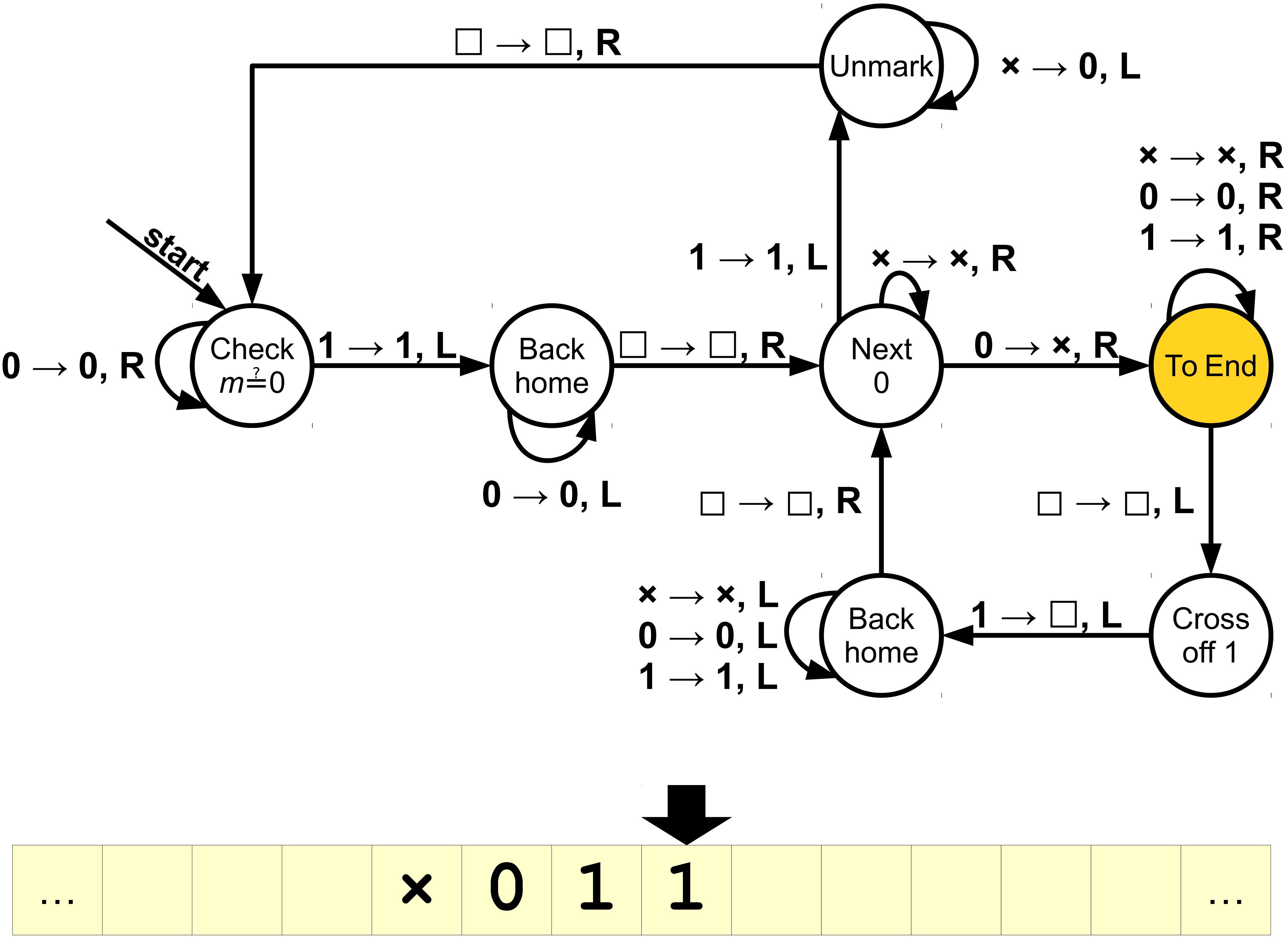
…				0	0	1	1						…

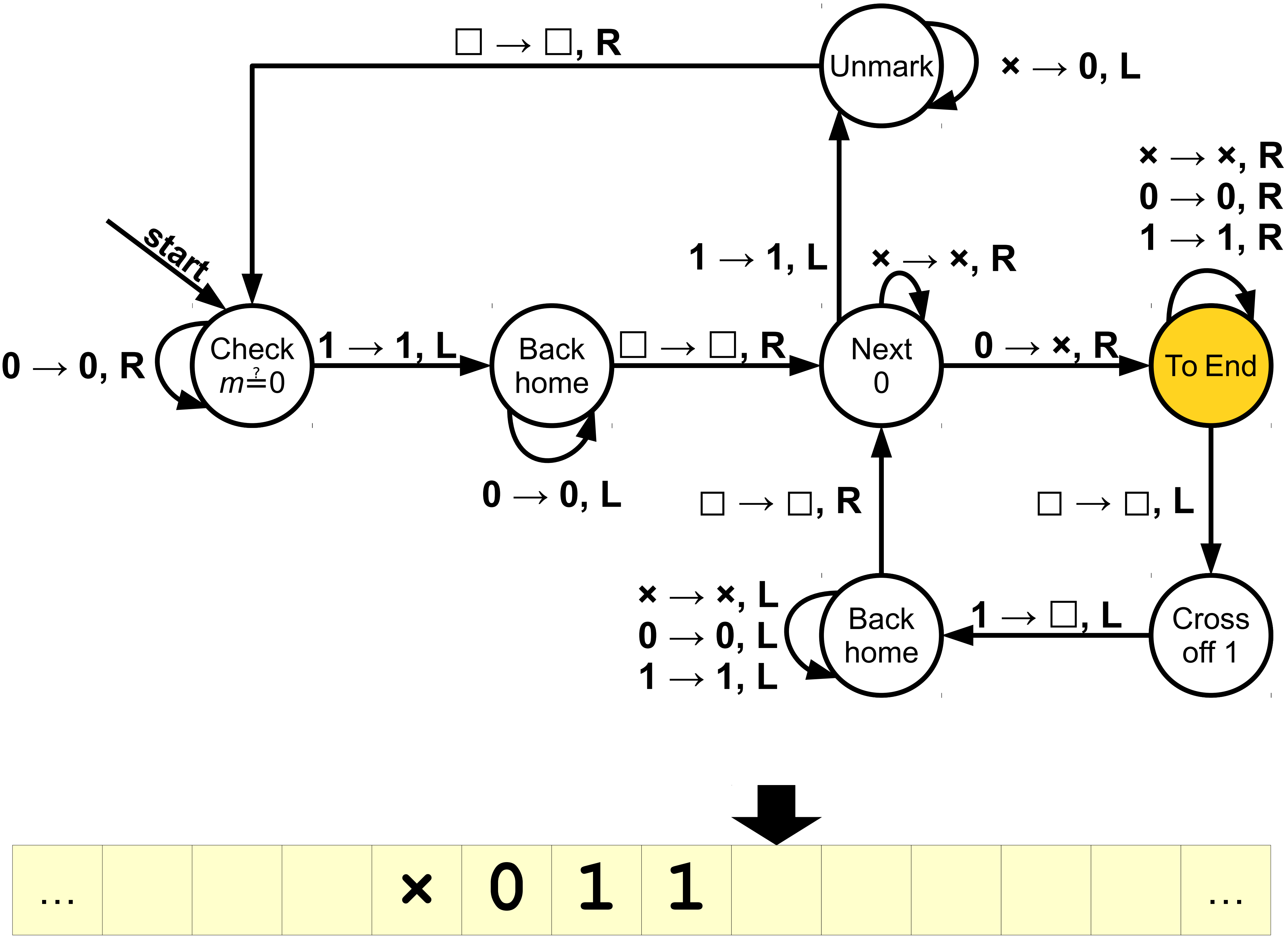

start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
0
0
1
1
…

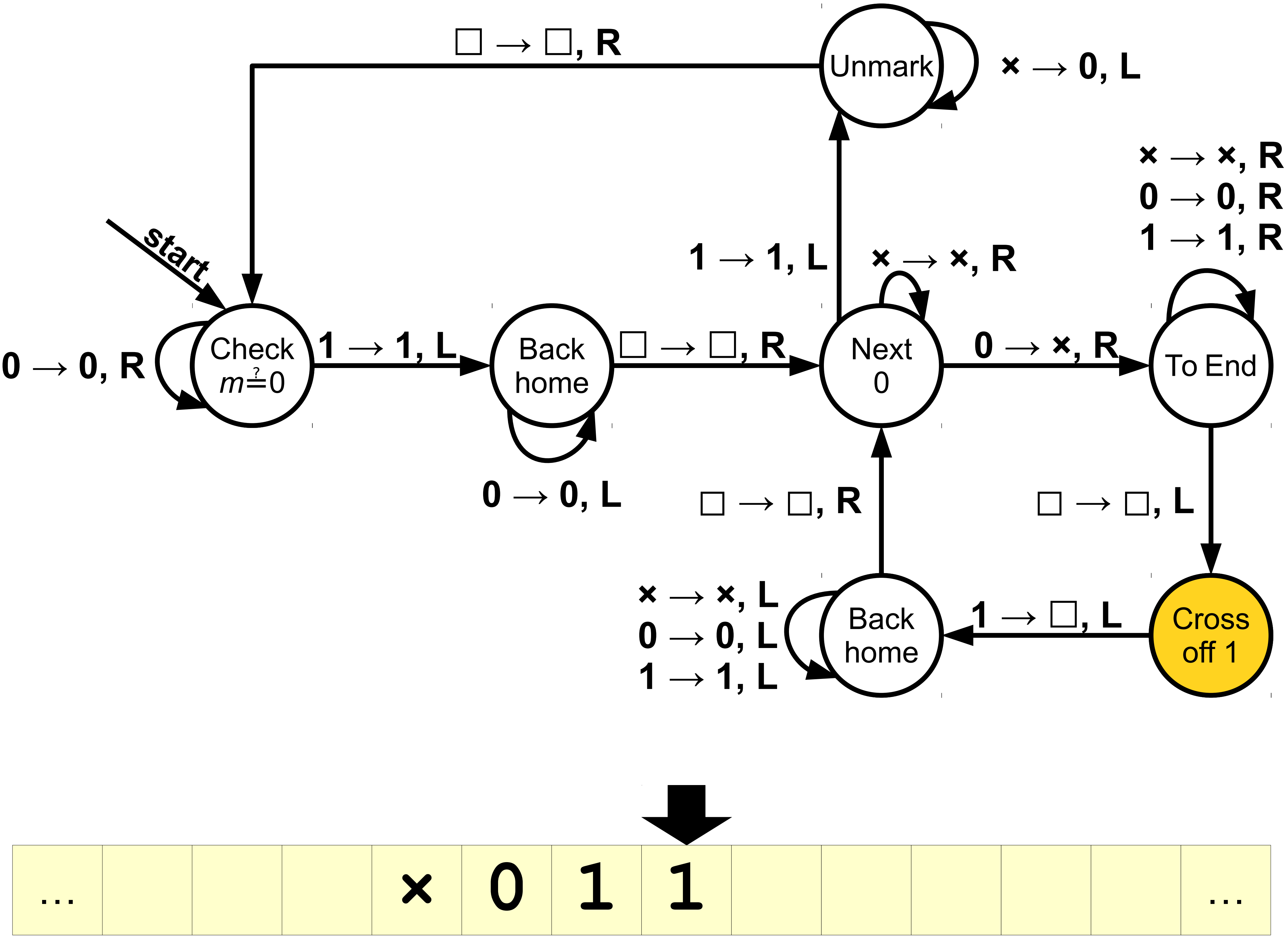

start
Check
$m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
× → ×, R
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
0
0
1
1
…


start
Check
m≟0
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
× → ×, R
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
0
1
1
…

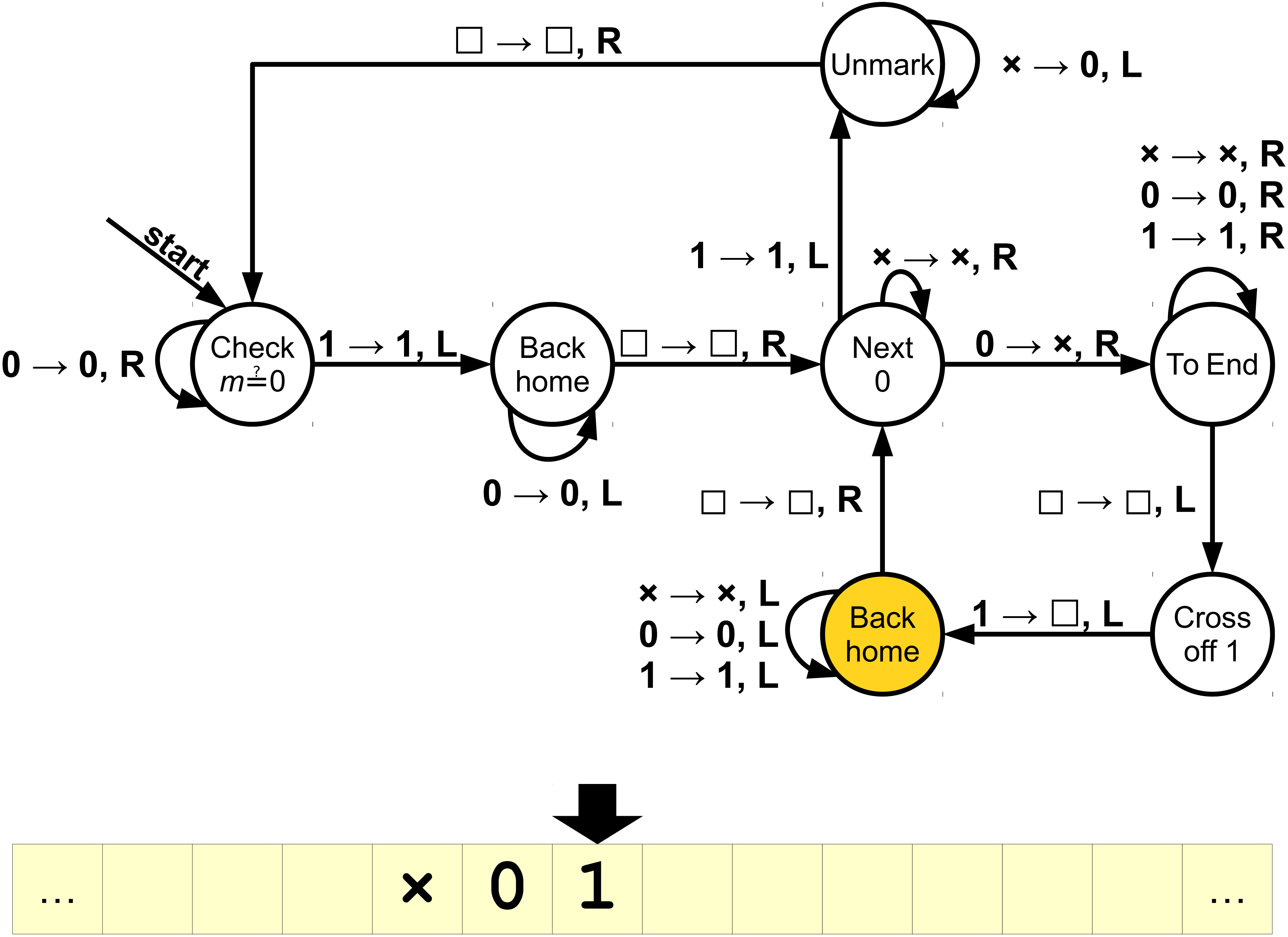

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
start
1 → 1, L
× → ×, R
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
1
1
…

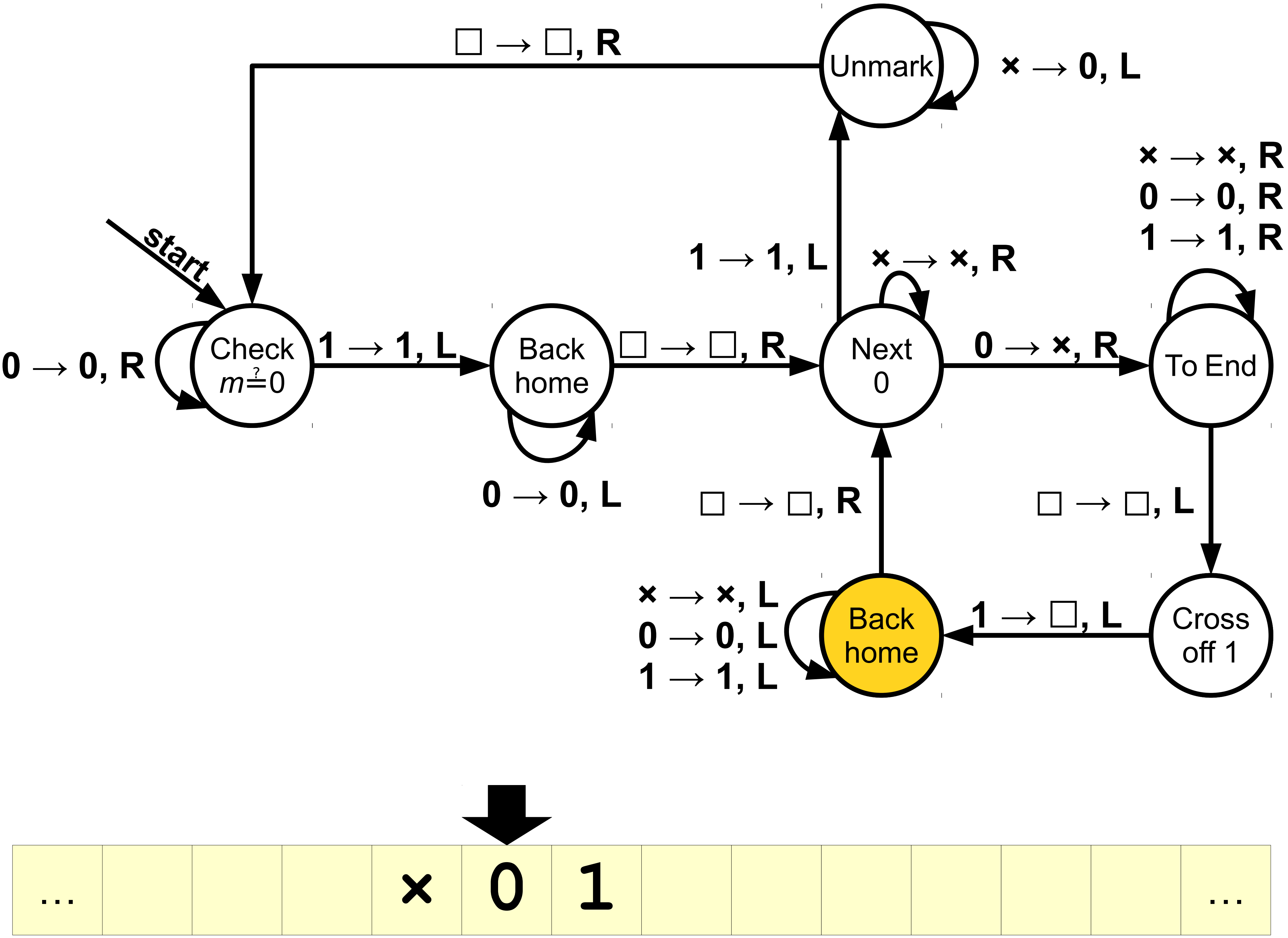

start
Check $m \stackrel{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
0
1
1
…

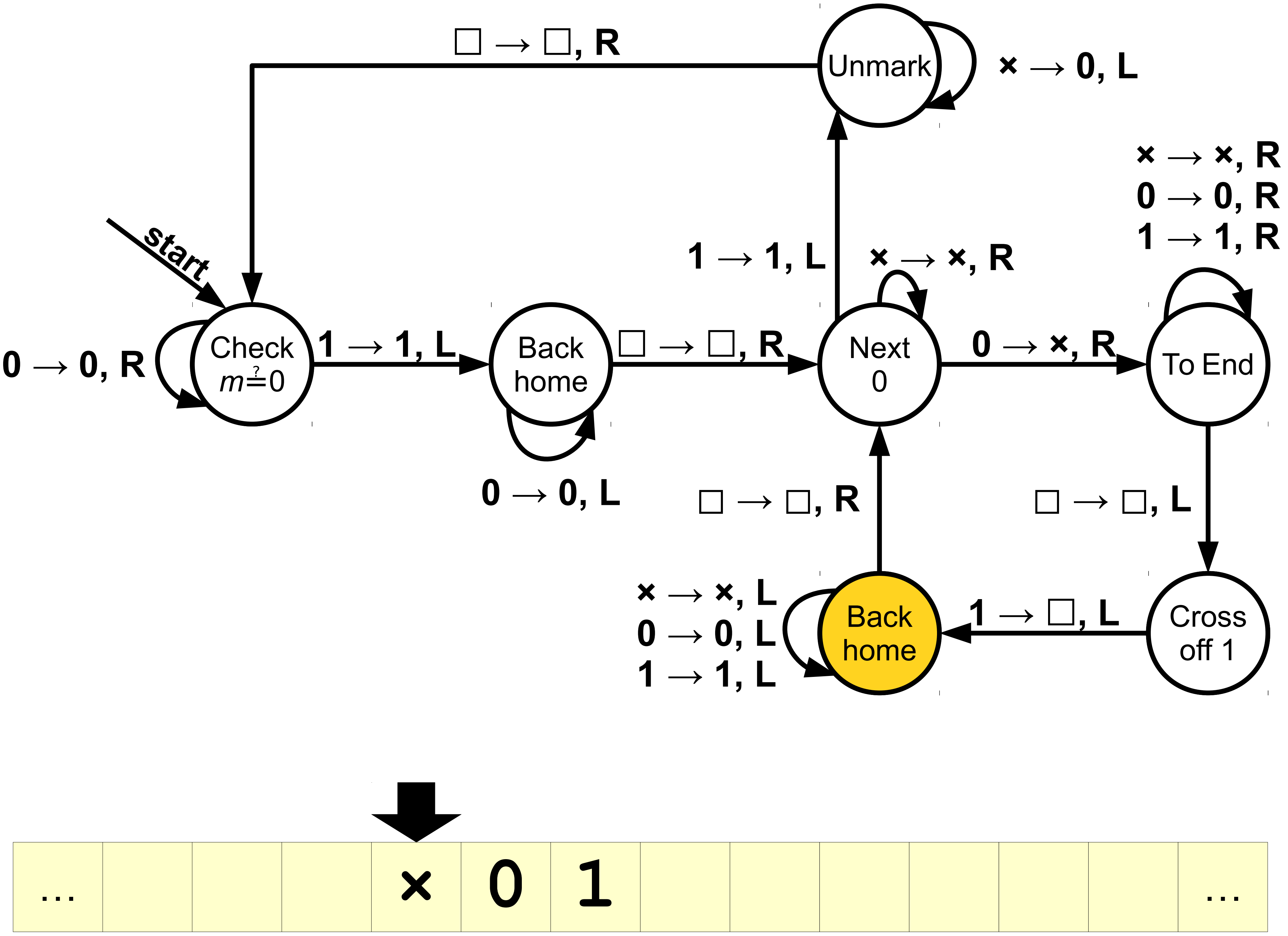

start
Check
$m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
× → ×, R
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
0
1
1
…

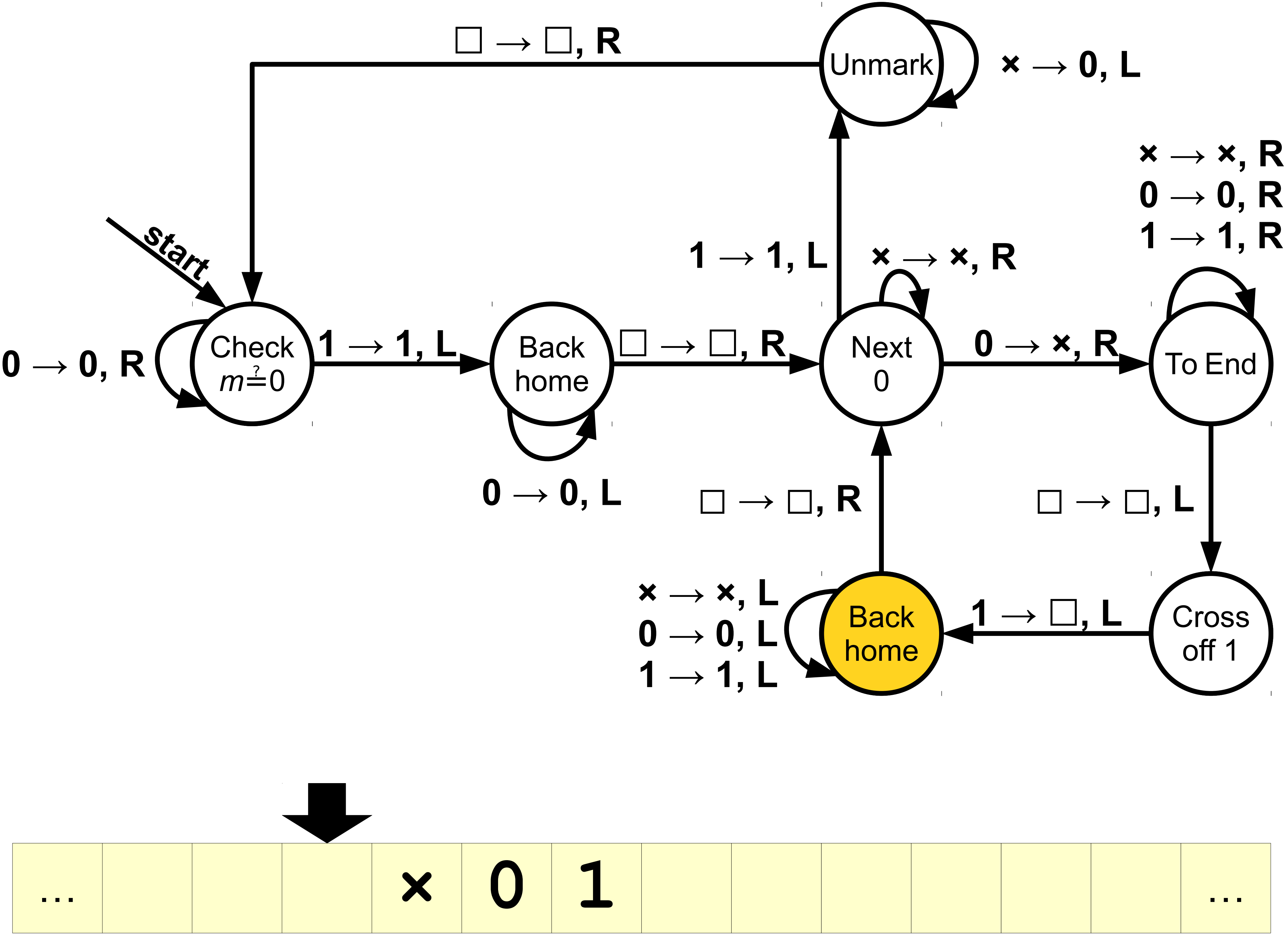

start
Check
$m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
× → ×, R
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R

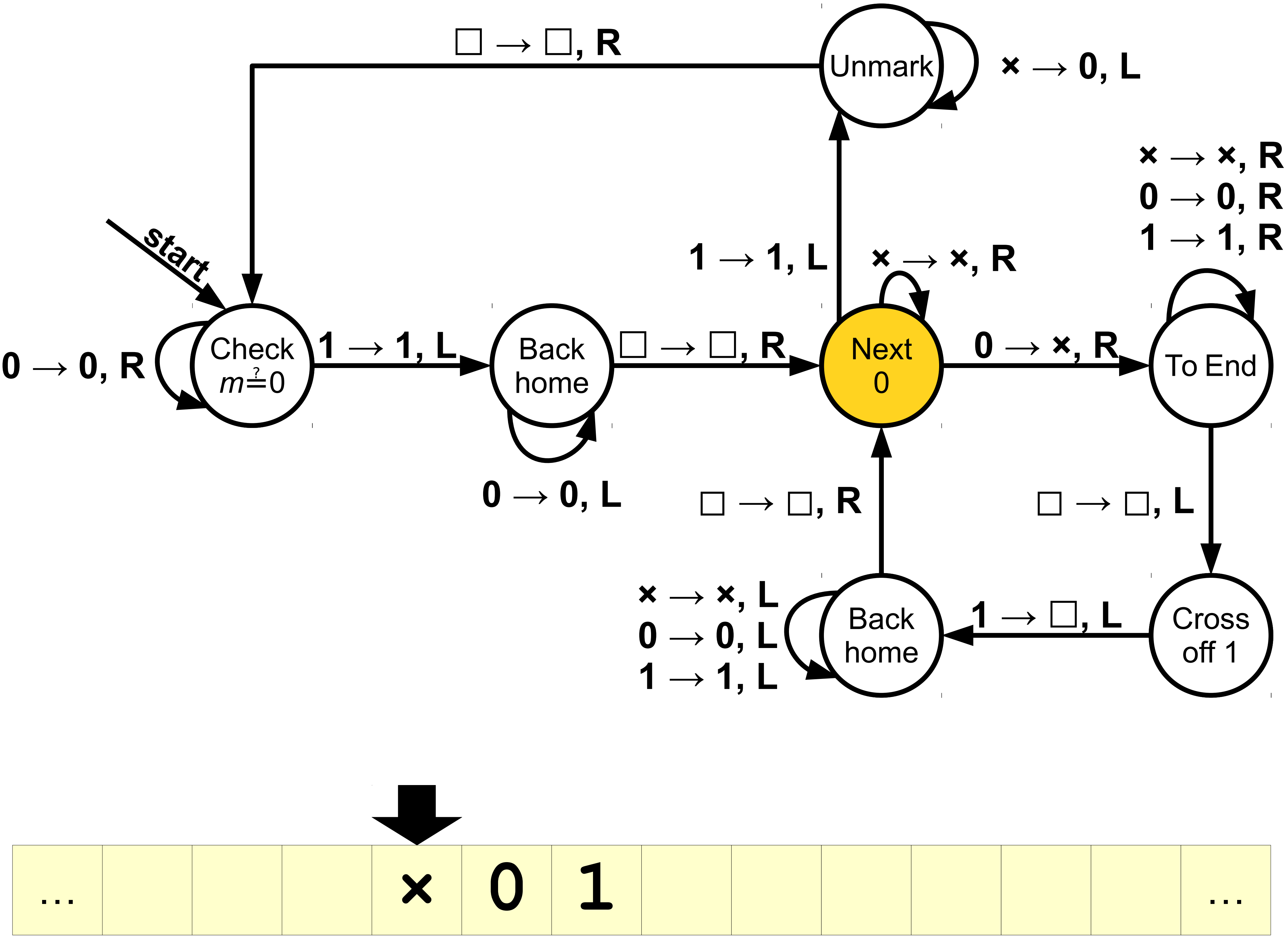
…				×	0	1	1						…

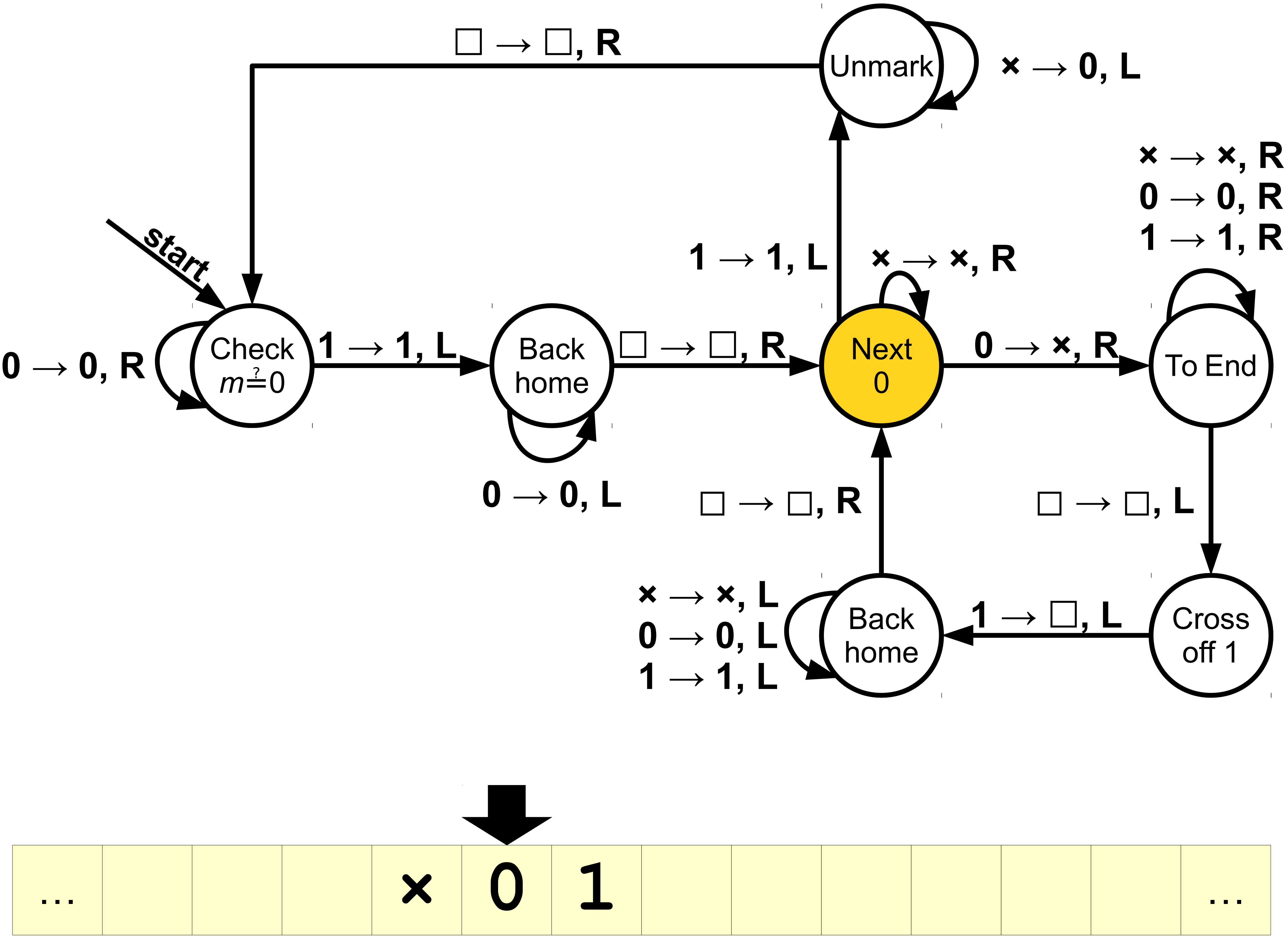

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
m≟0
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
1
…

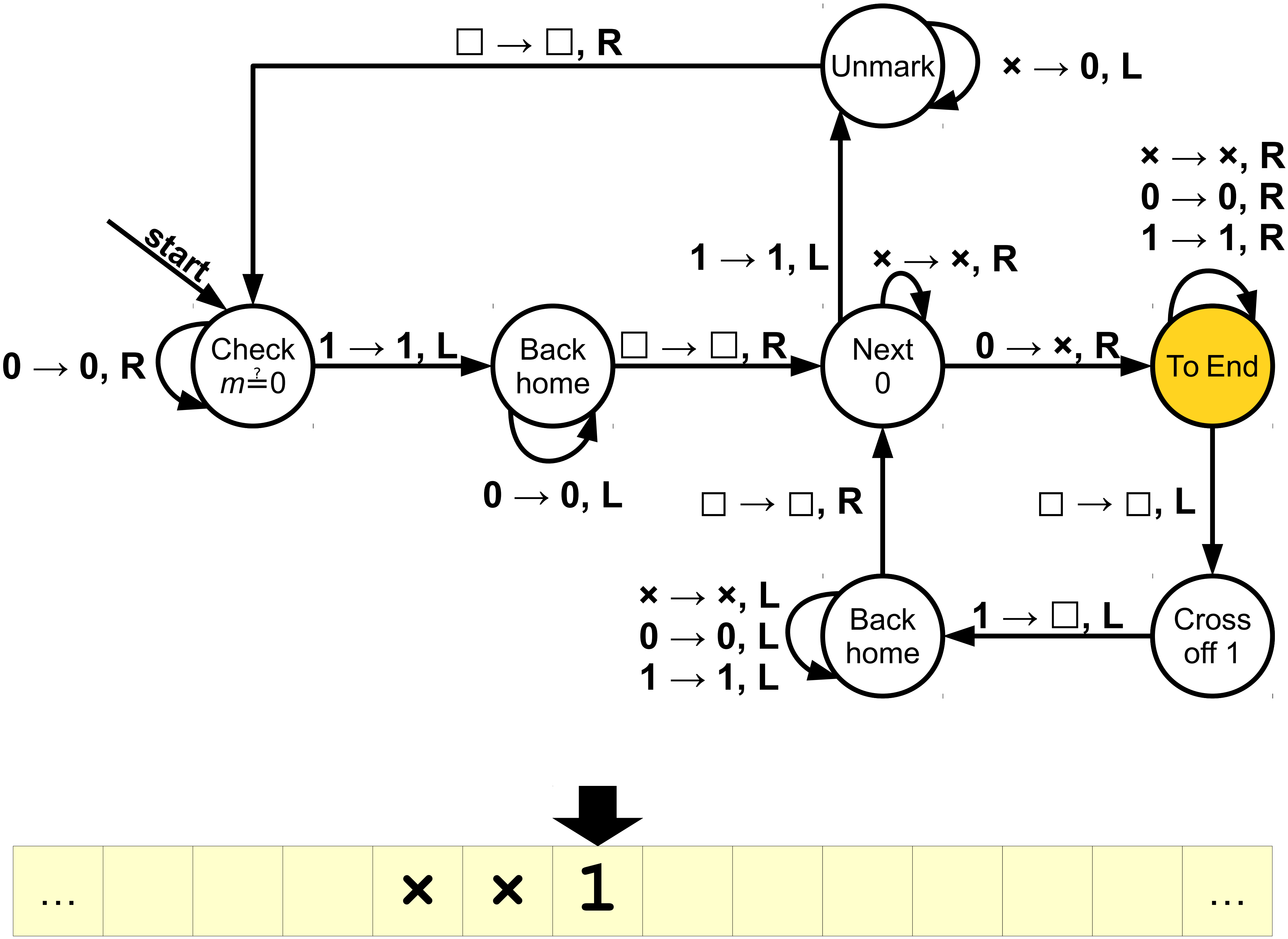

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
1
…

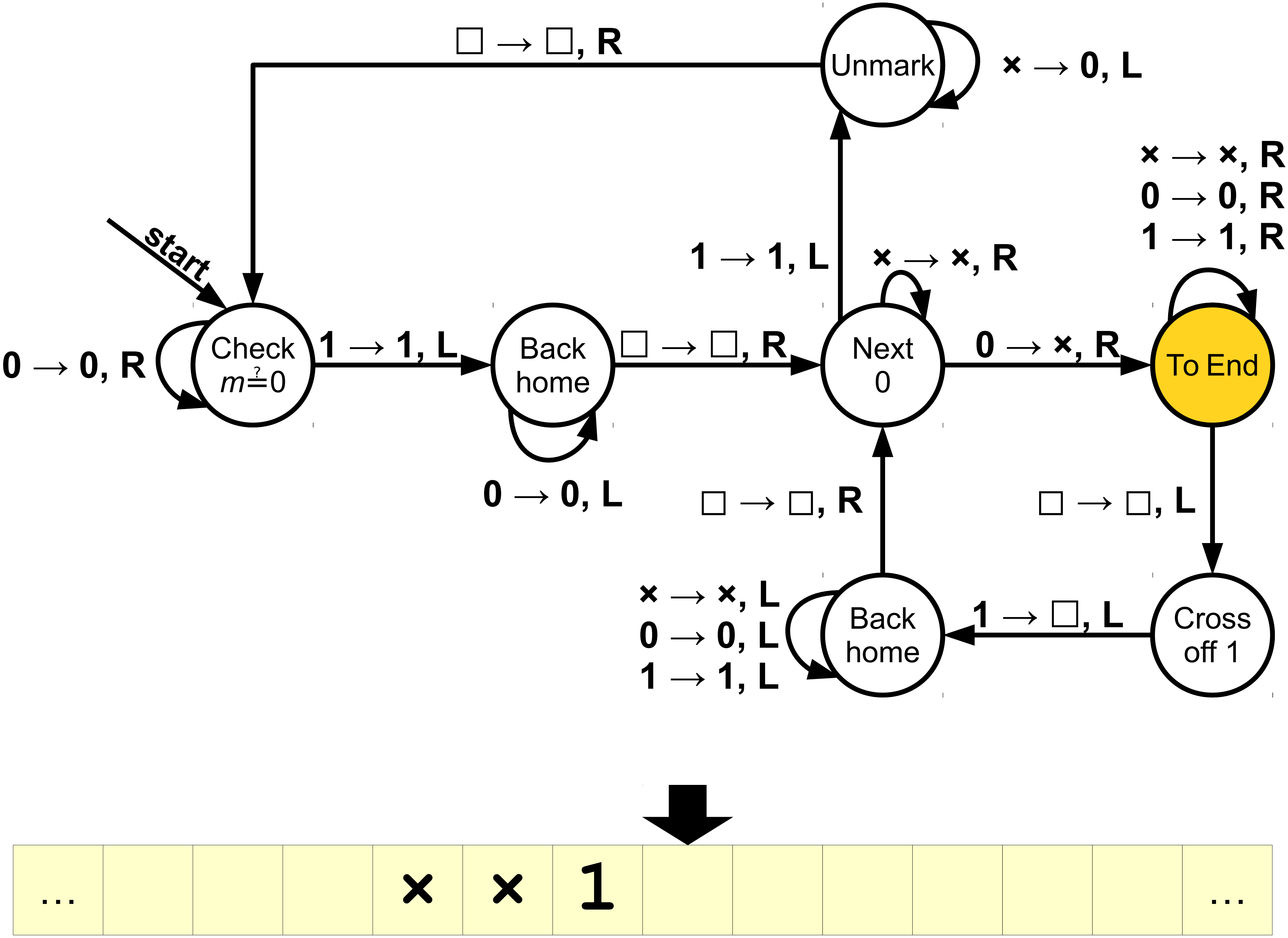

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
start
1 → 1, L
× → ×, R
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
1
…

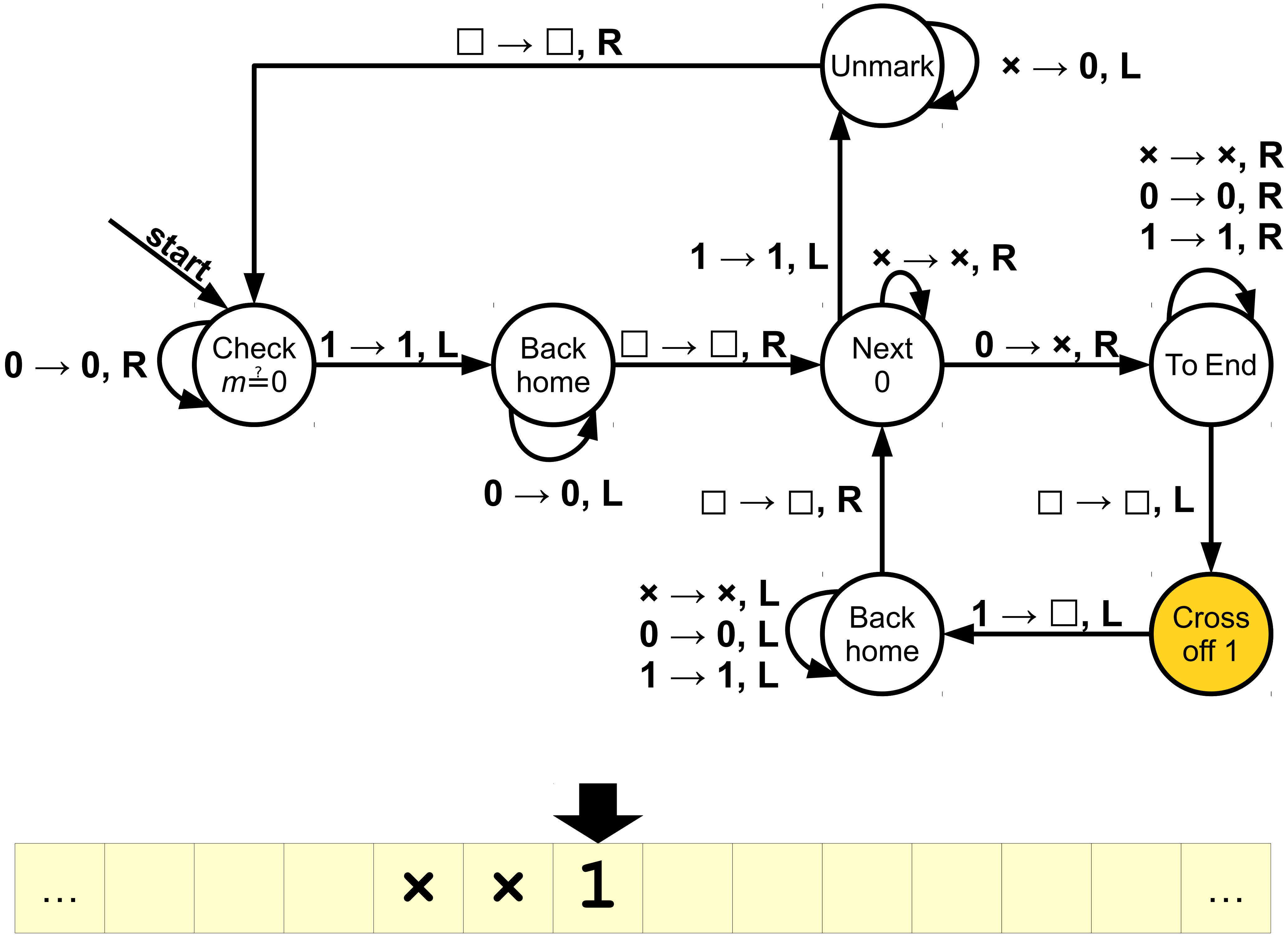

start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
0
1
…

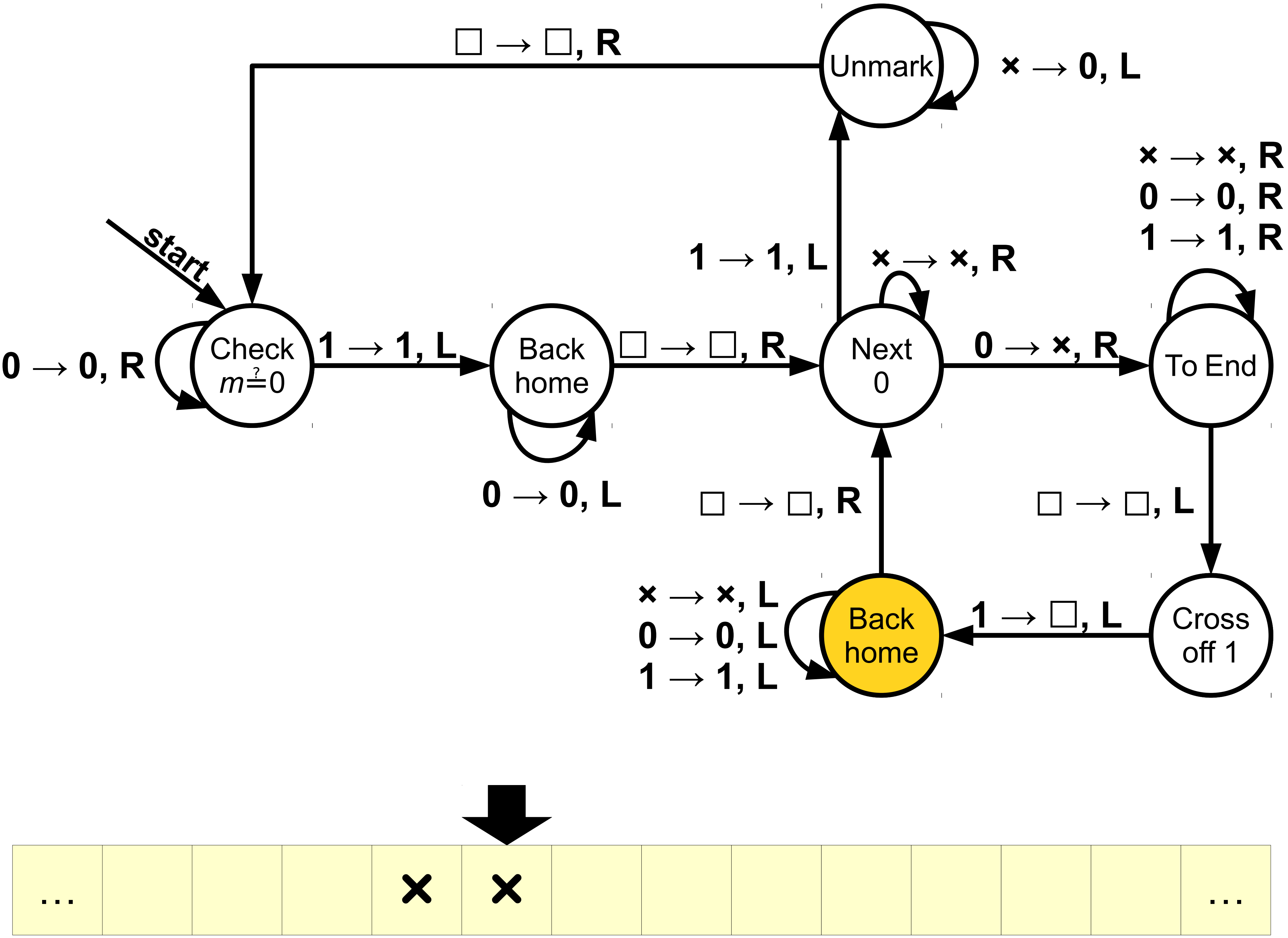

□ → □, R
Unmark
× → 0, L
start
1 → 1, L
× → ×, R
× → ×, R
0 → 0, R
1 → 1, R
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
1
…

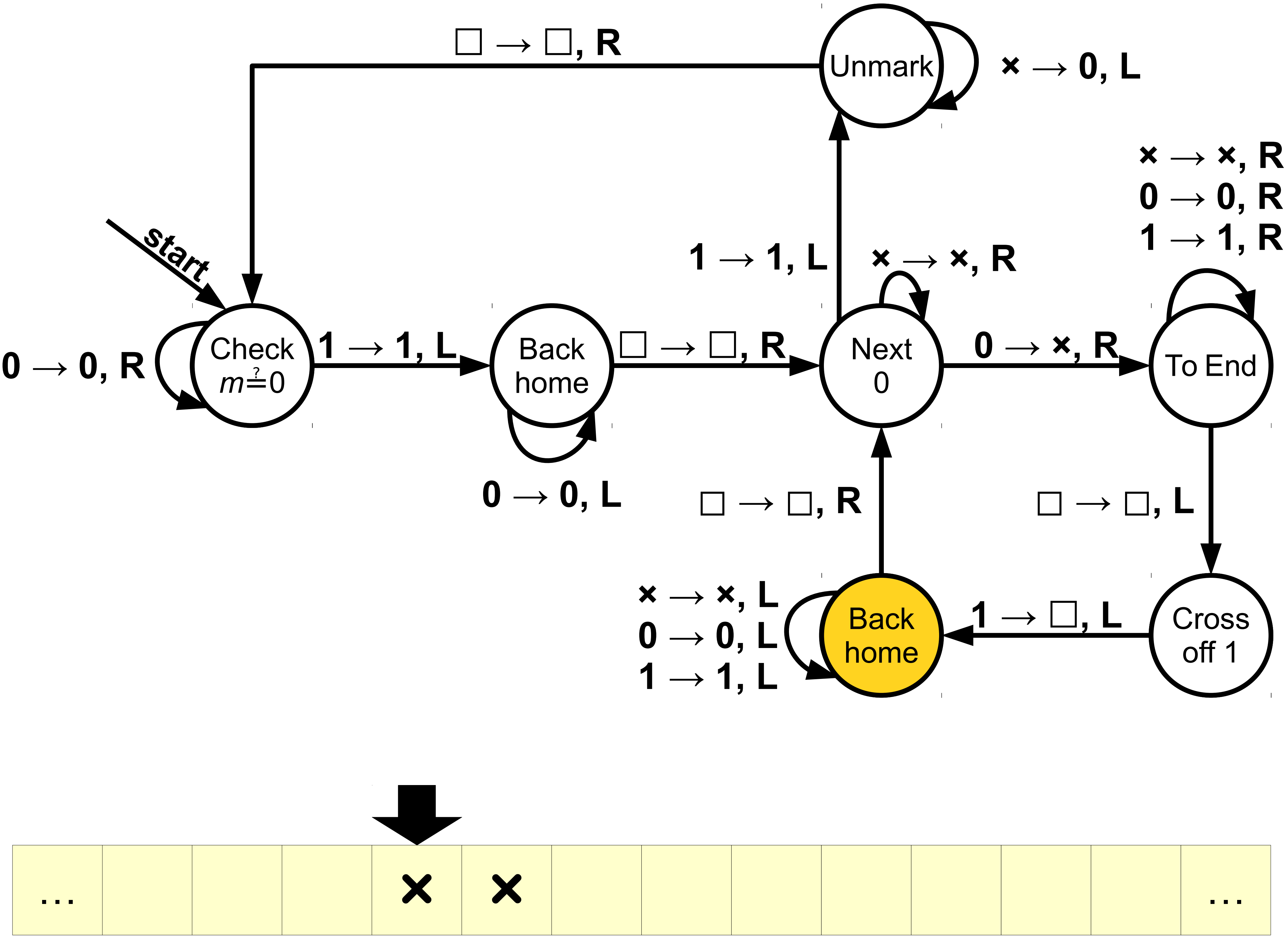

start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
0
1
…

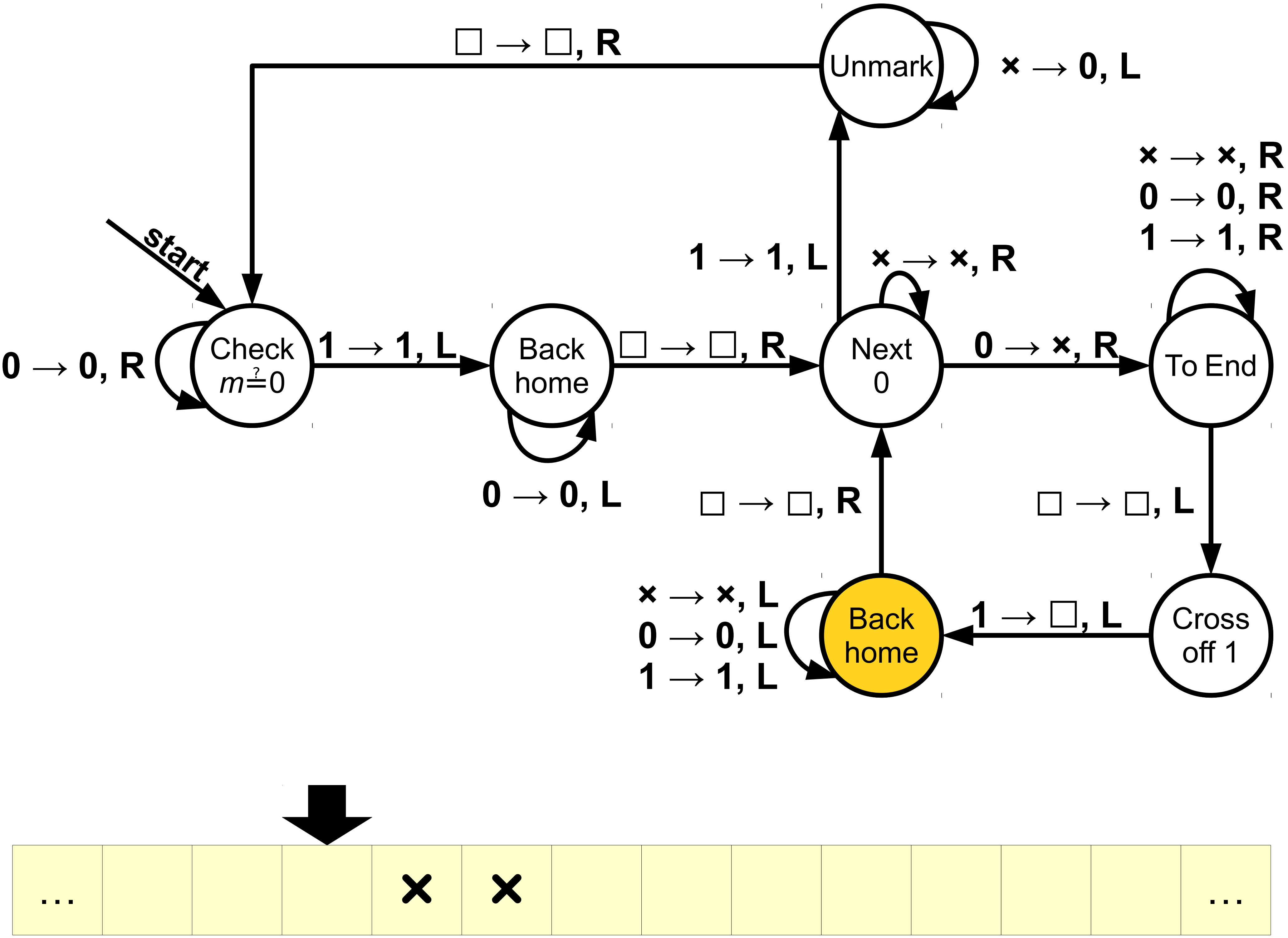

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
start
1 → 1, L
× → ×, R
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
×
1
…

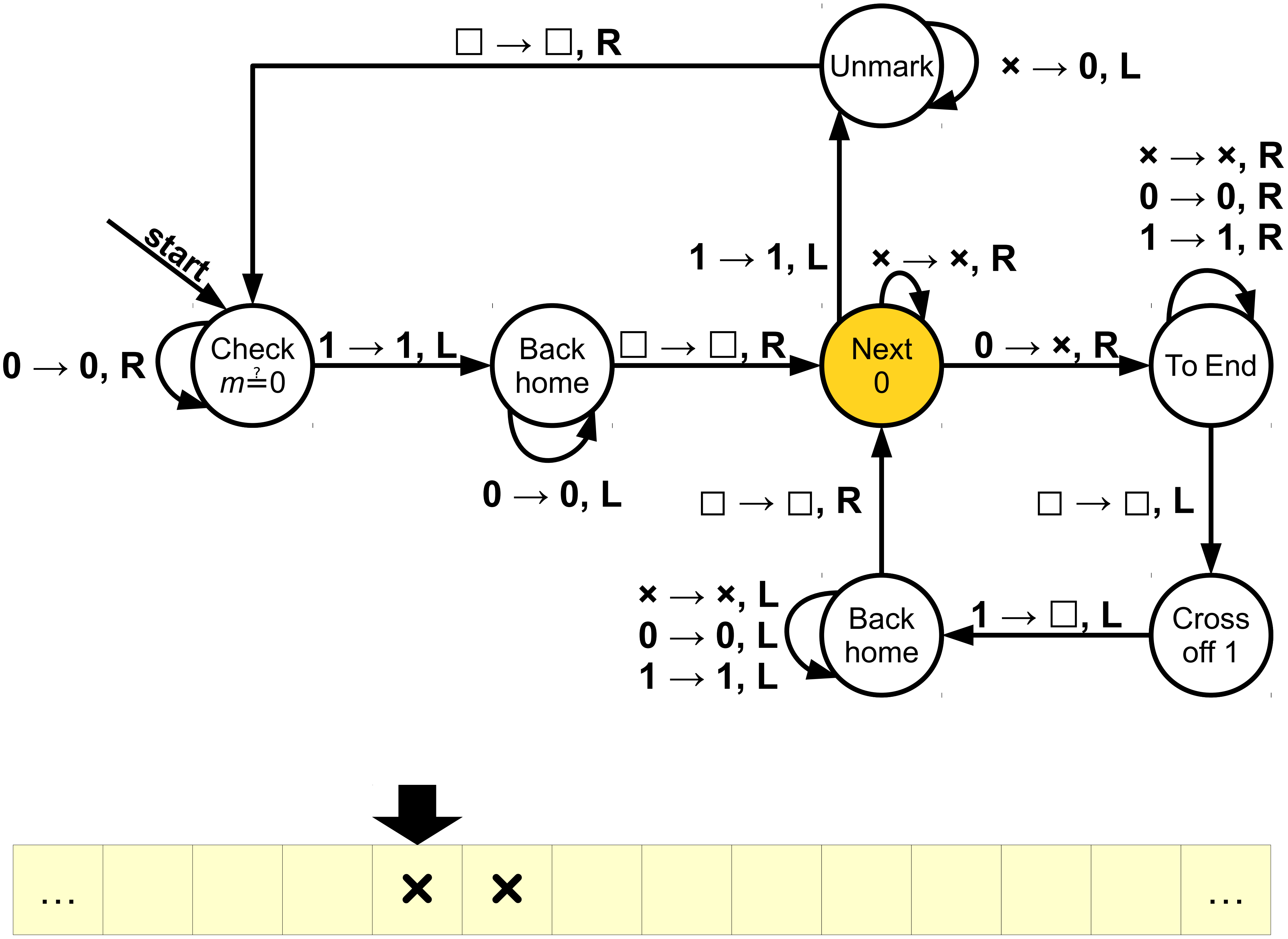

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
start
1 → 1, L
× → ×, R
0 → 0, R
Check $m \overset{?}{=} 0$
1 → 1, L
Back home
□ → □, R
Next 0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back home
1 → □, L
Cross off 1
…
×
×
1
…

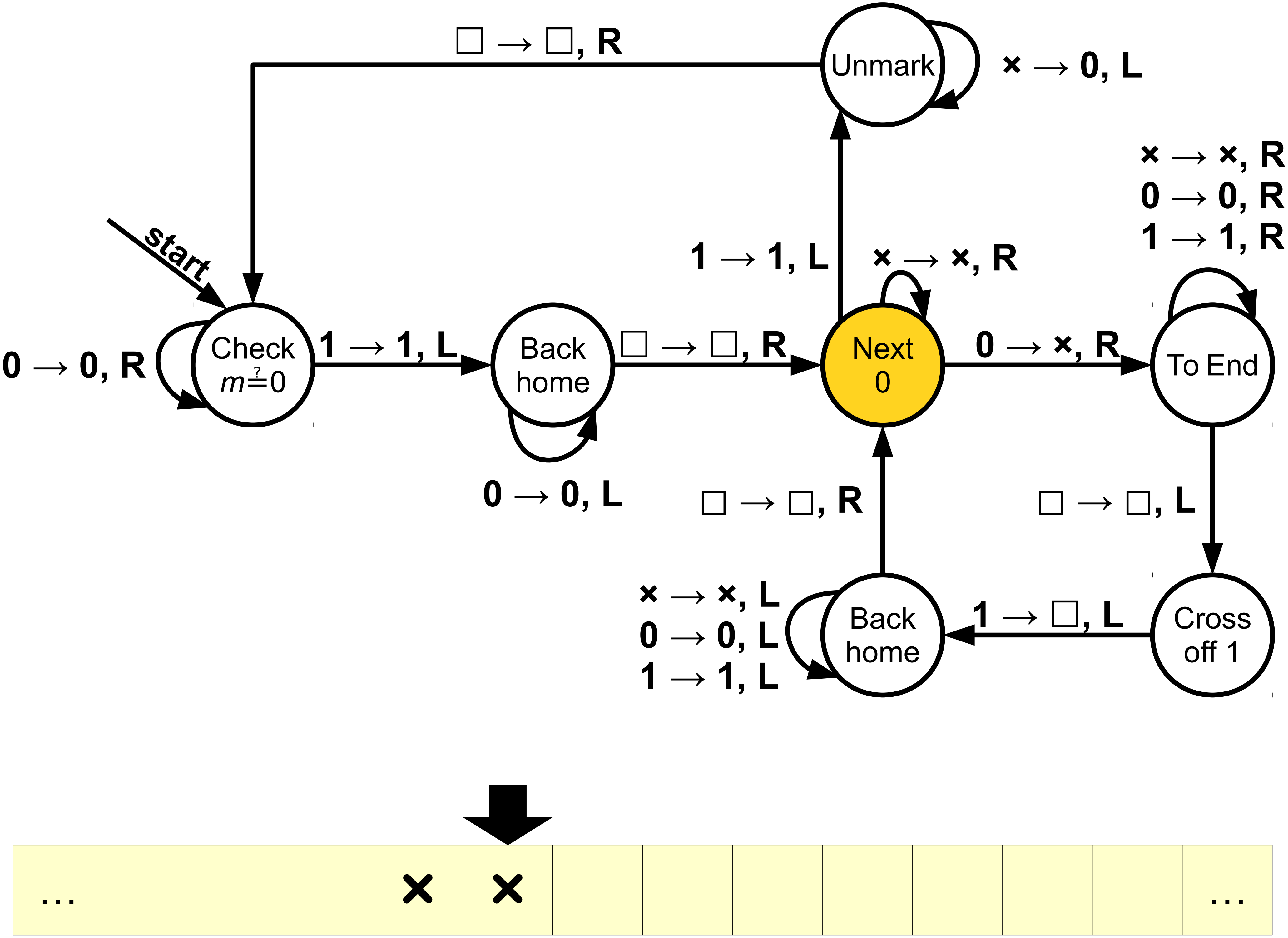

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
Check
$m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
0 → ×, R
To End
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back home
1 → □, L
Cross off 1
…
×
×
1
…

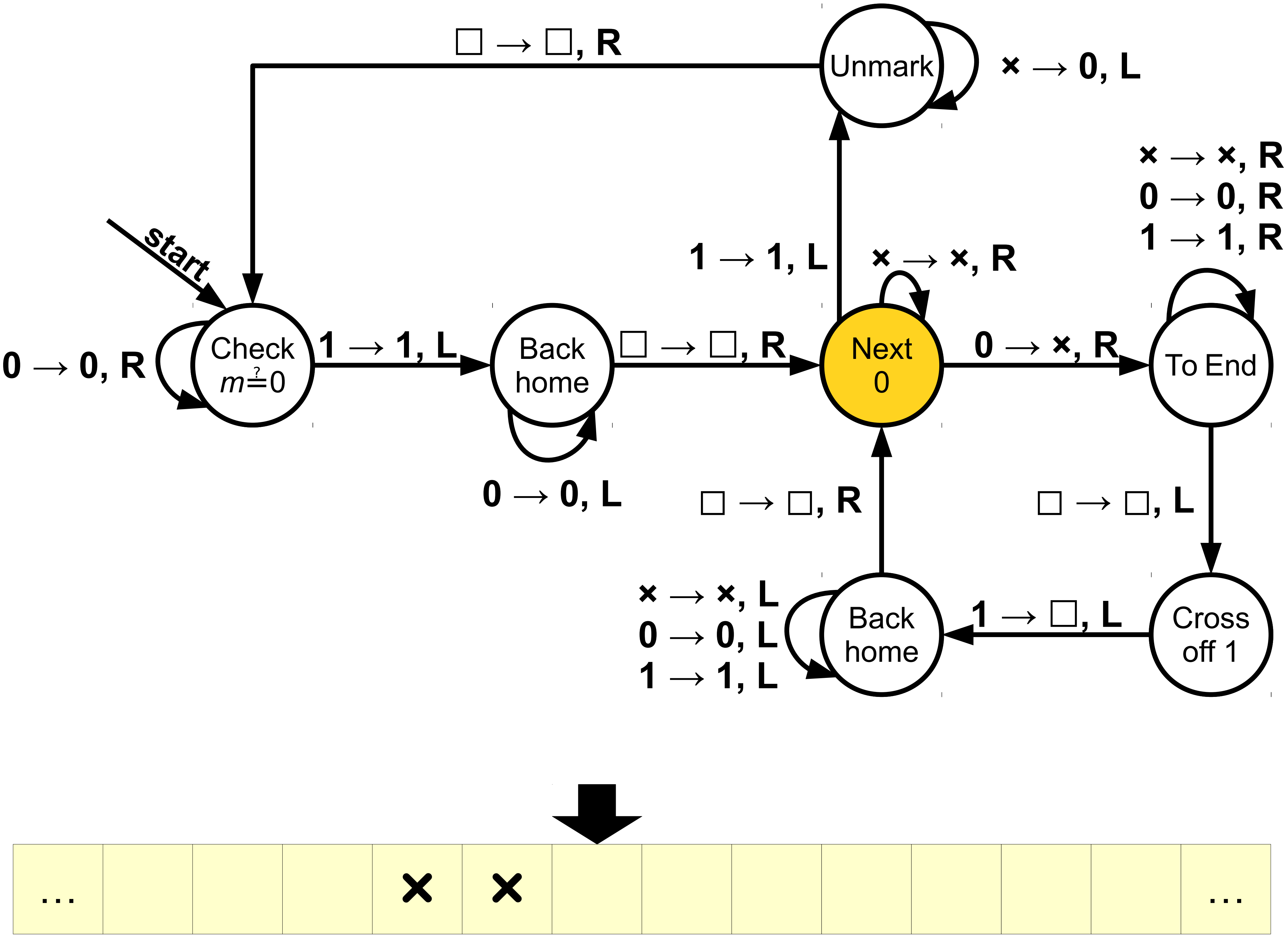

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check $m \overset{?}{=} 0$
1 → 1, L
Back home
□ → □, R
Next 0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back home
1 → □, L
Cross off 1
…
×
×
…


□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
×
…

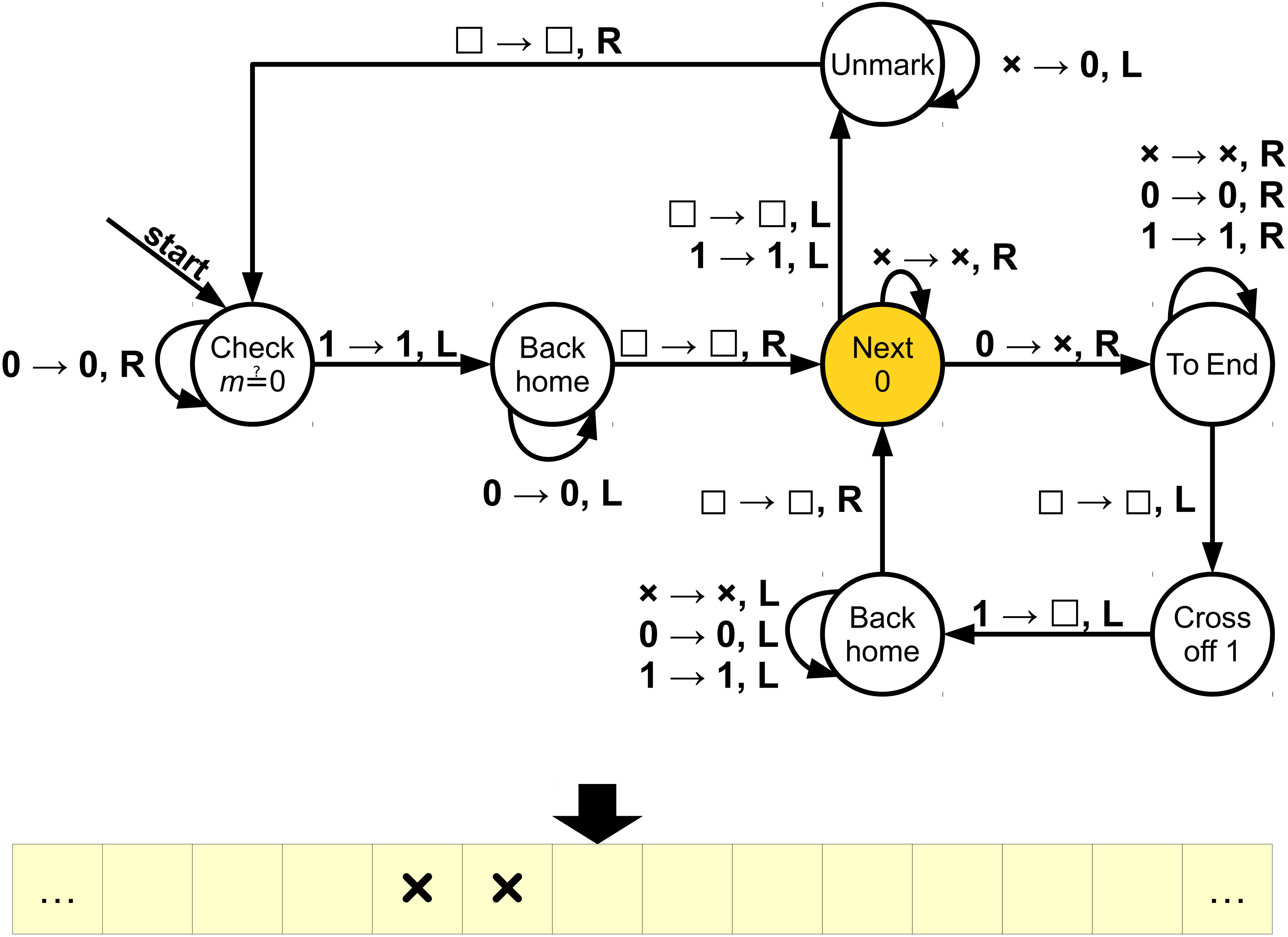

start
Check
m≟0
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
× → ×, R
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
…

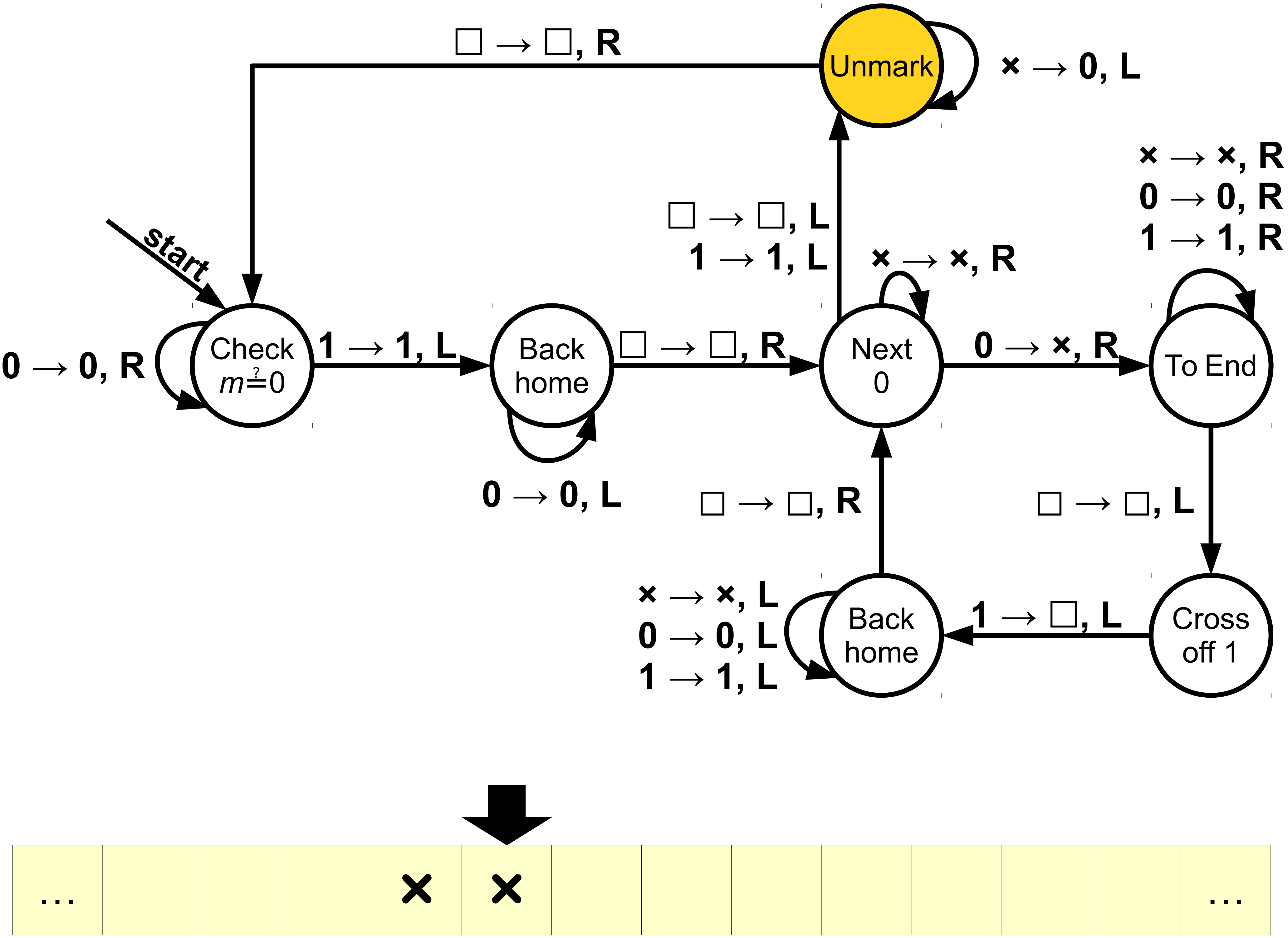

□ → □, R
Unmark
× → 0, L
start
Check
m ≟ 0
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
1 → 1, L
× → ×, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, R
□ → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
1 → □, L
Cross
off 1
…
×
×
…


□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
×
…

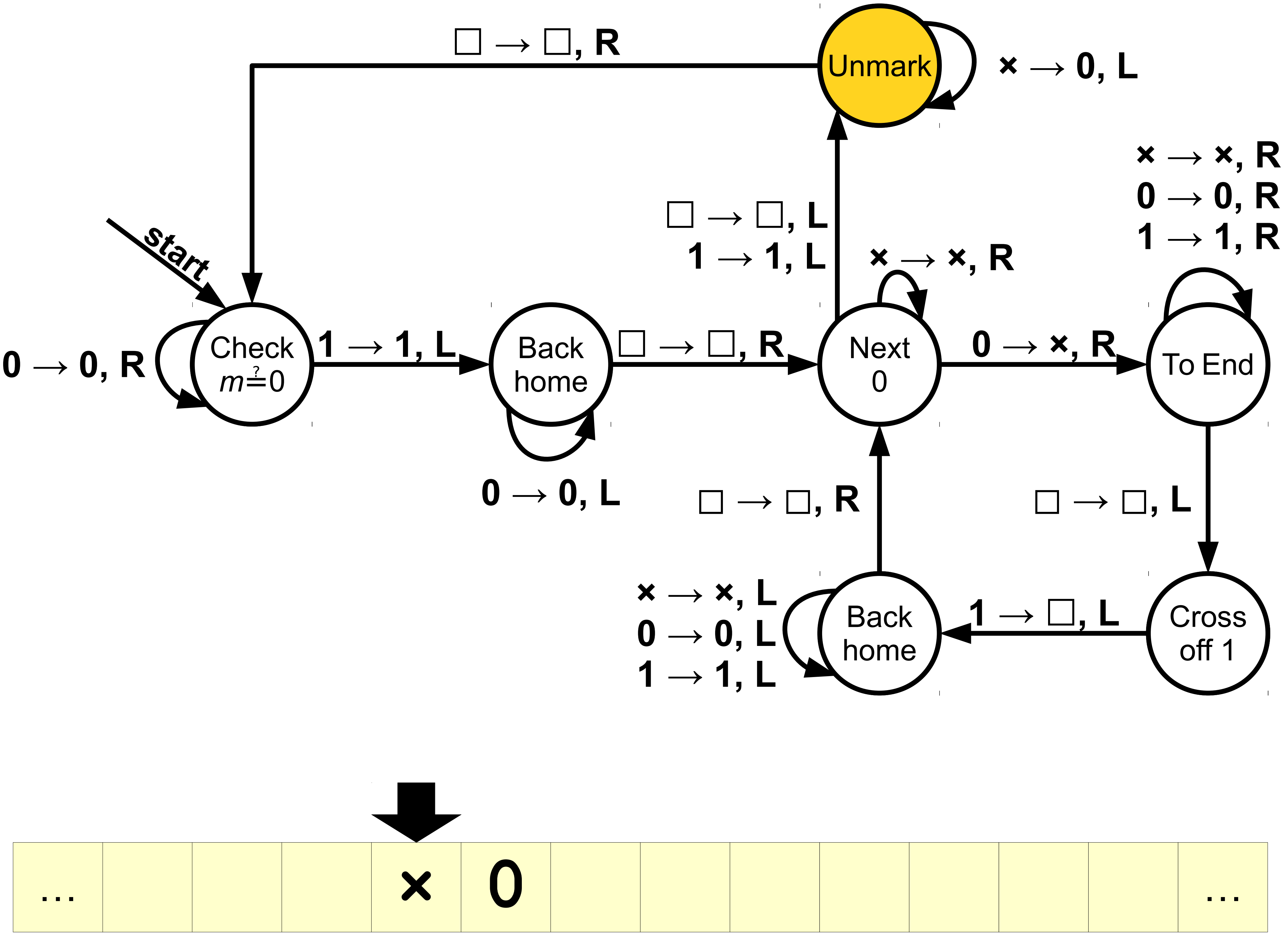


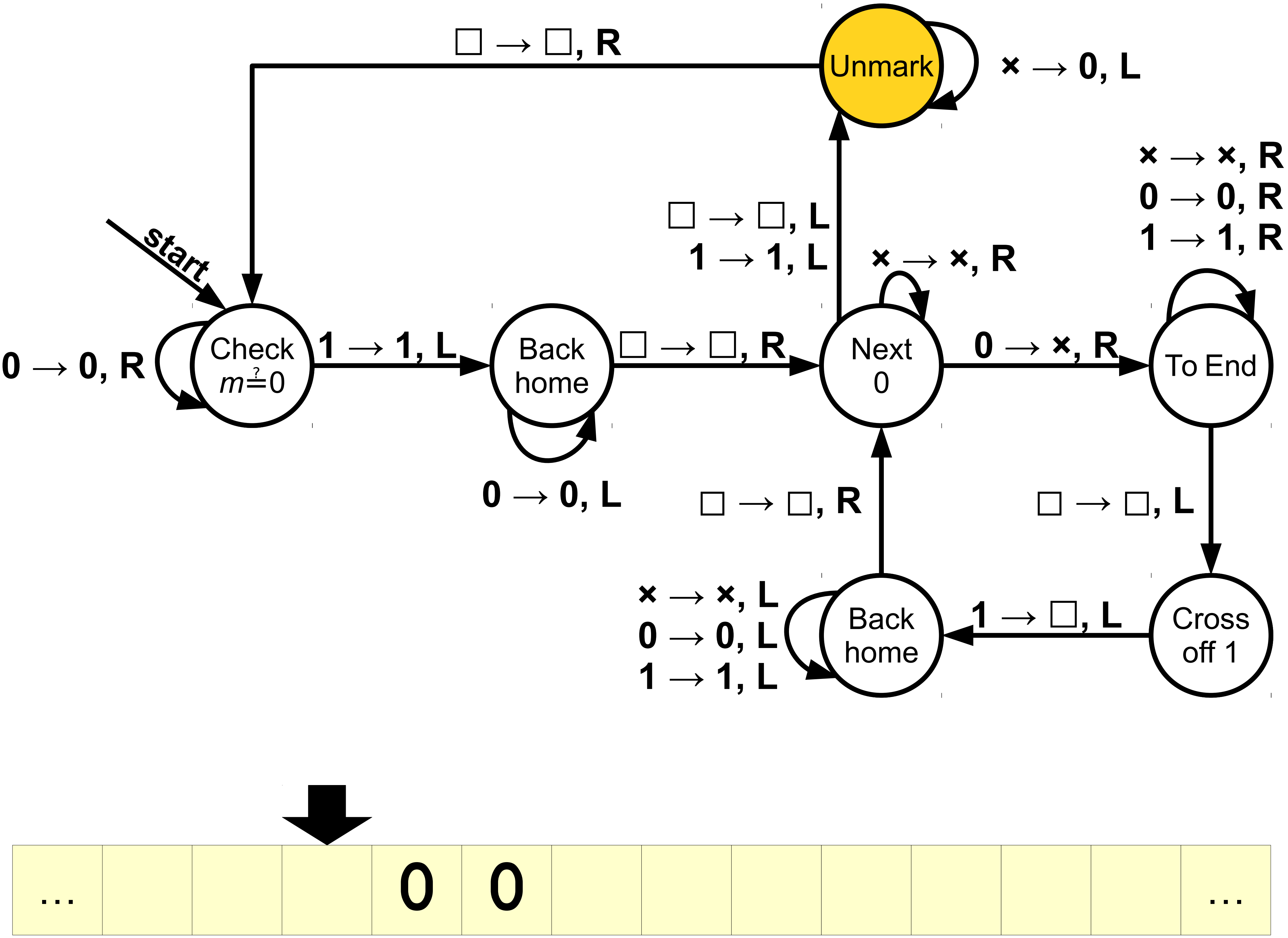
start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
…

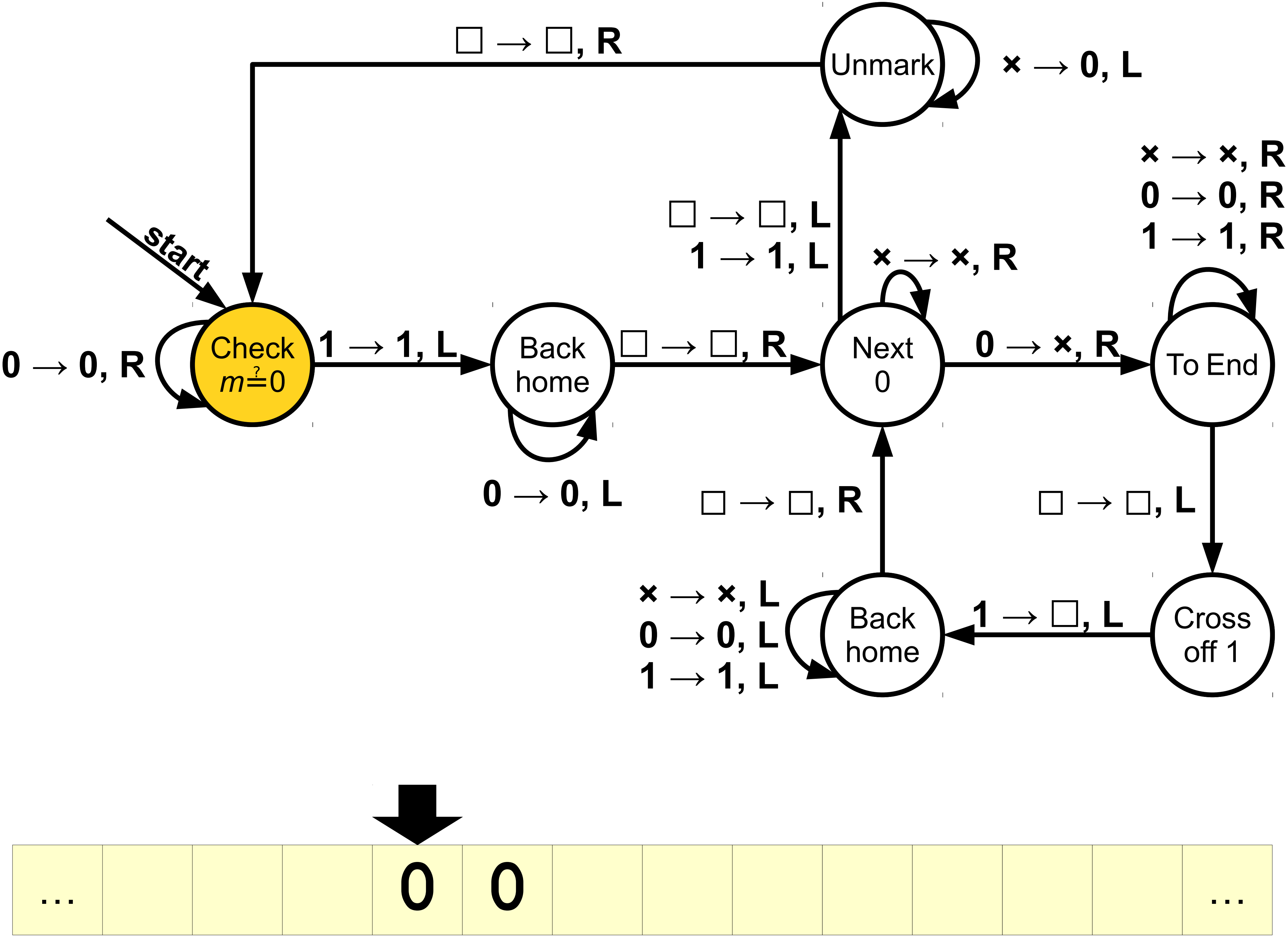

start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
□ → □, L
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
…

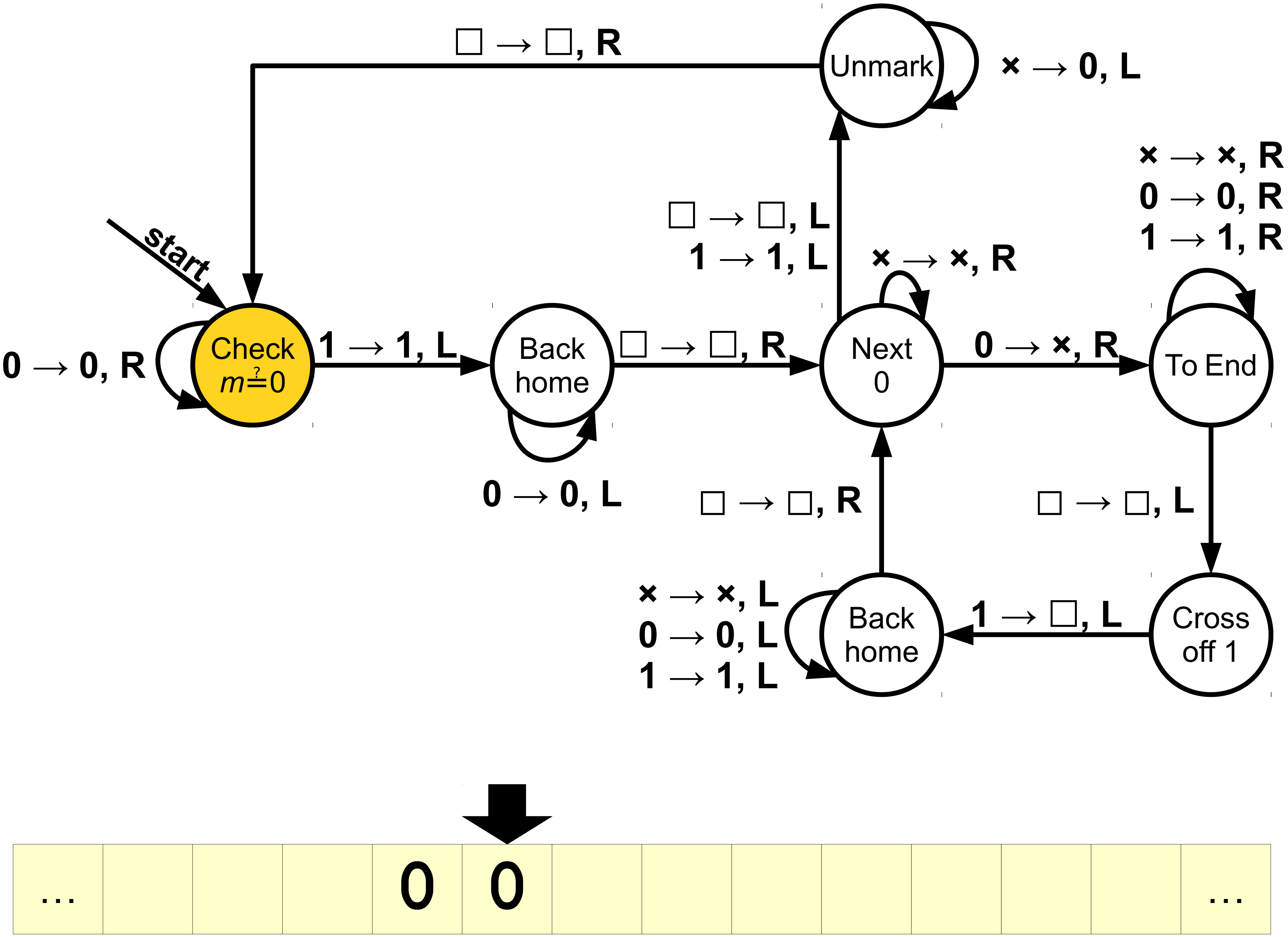


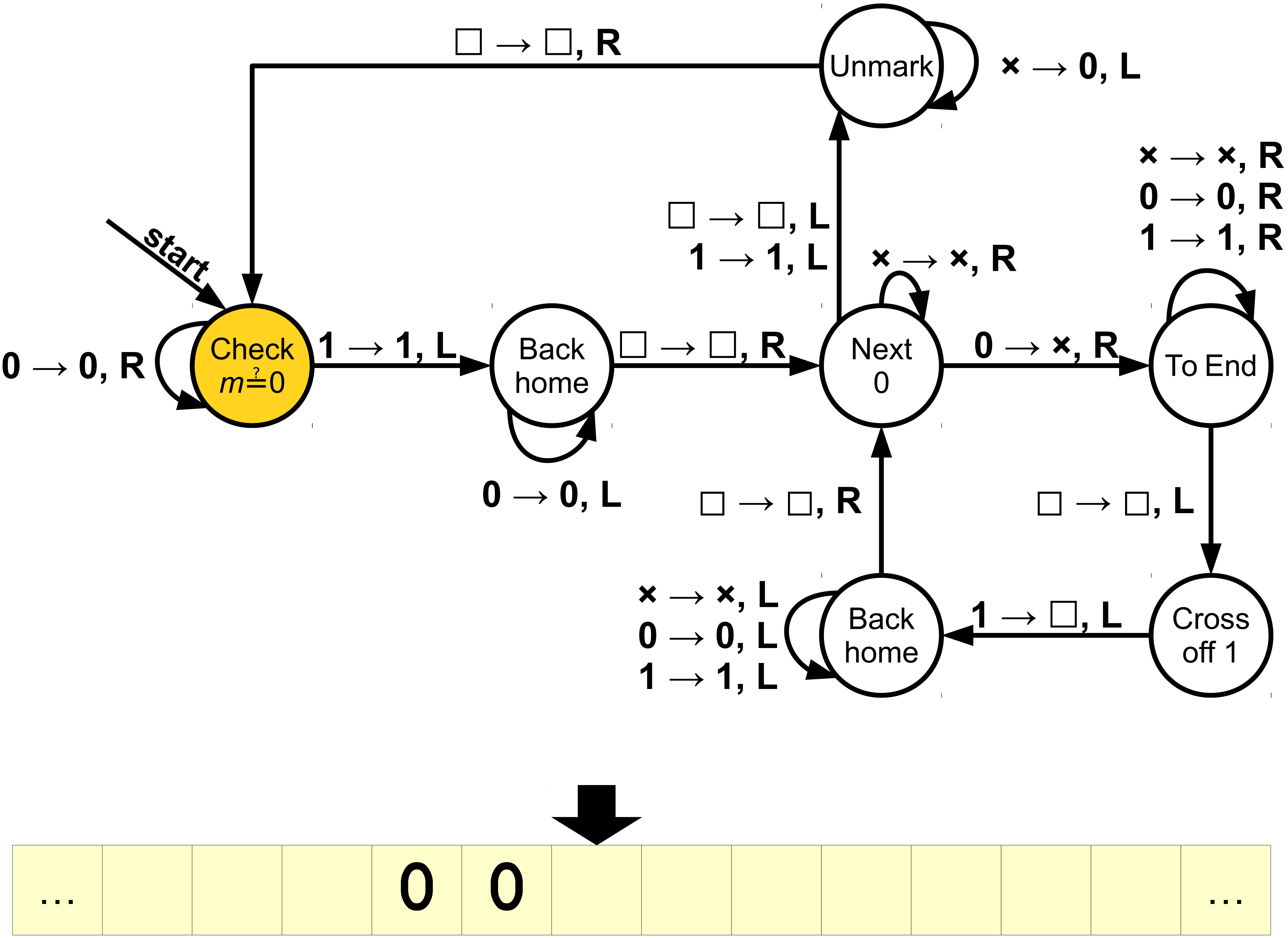
start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
□ → □, L
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
…

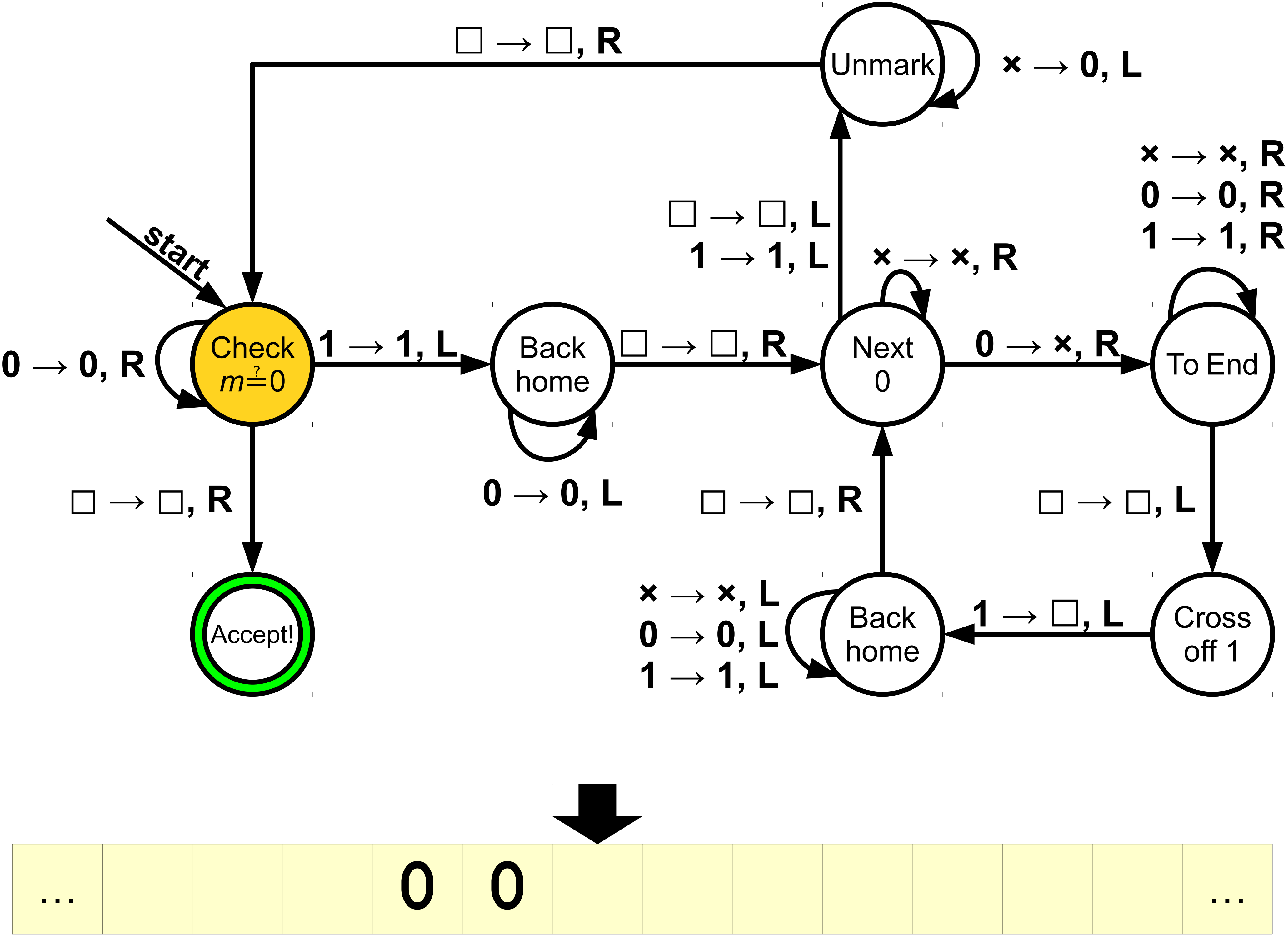

start
Check
m ≟ 0
0 → 0, R
1 → 1, L
Back
home
0 → 0, L
□ → □, R
Next
0
× → ×, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
□ → □, L
1 → 1, L
Unmark
× → 0, L
□ → □, R
…
×
0
…

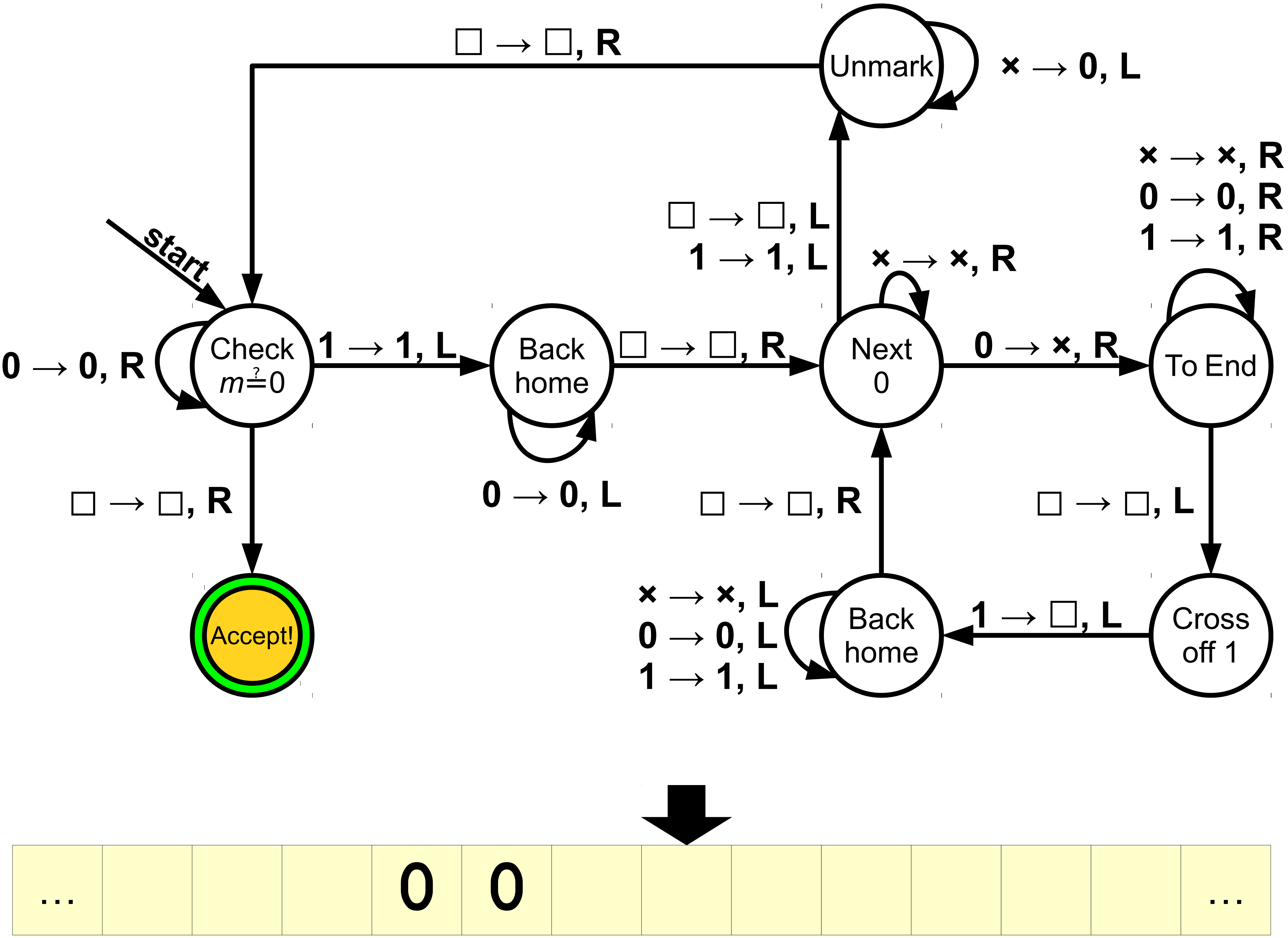

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
0
0
…

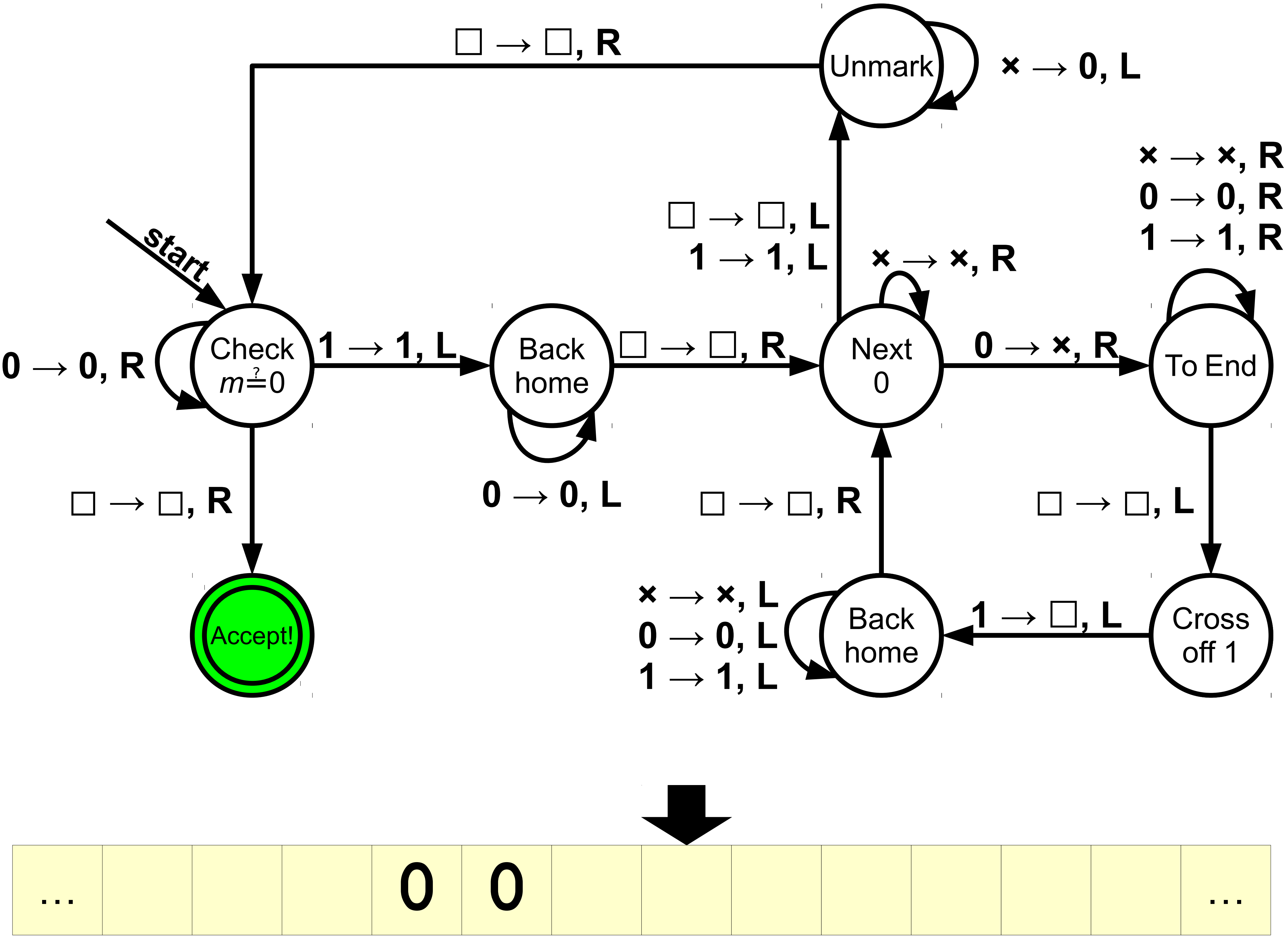

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
0
0
…

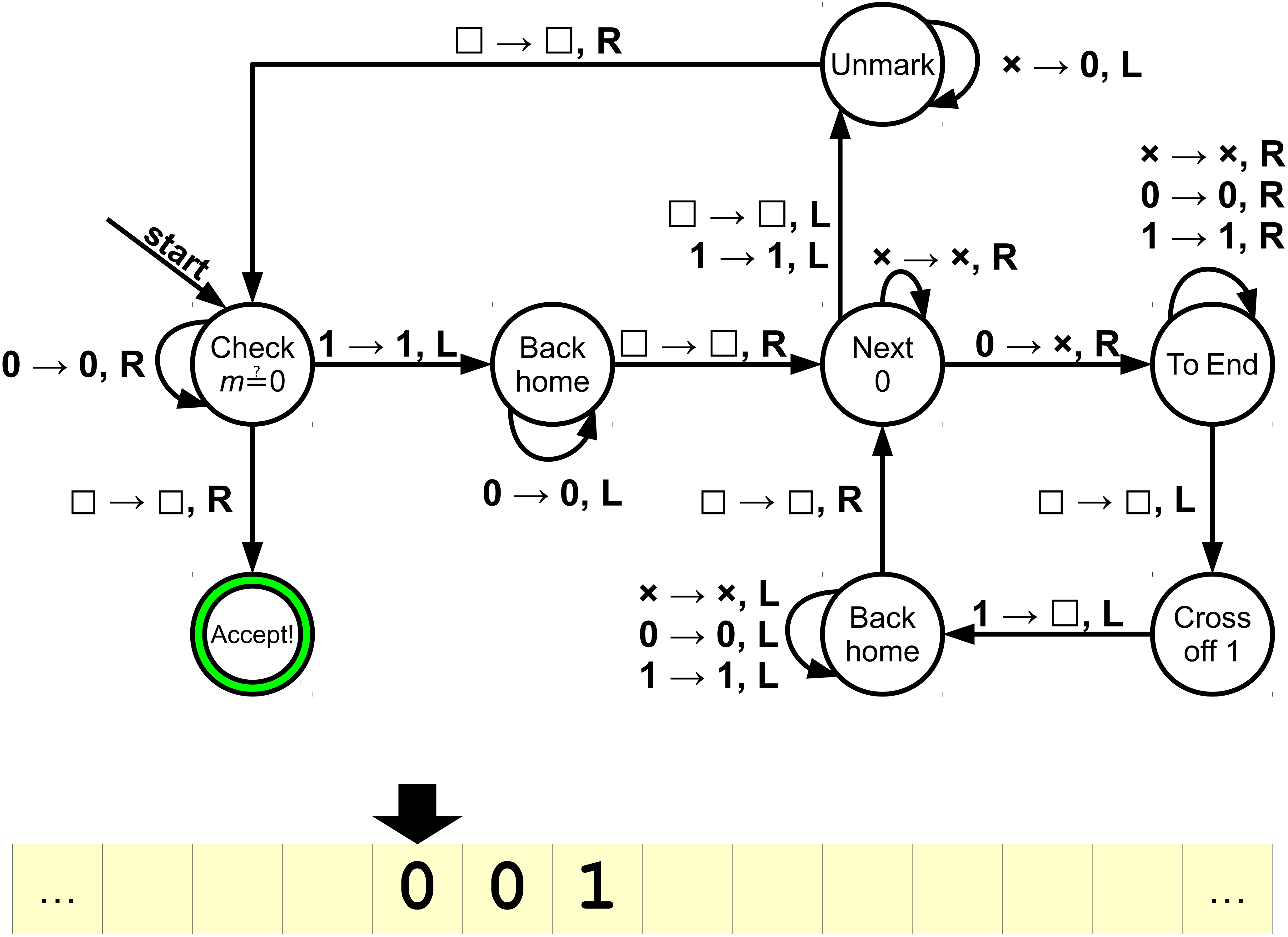

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back home
□ → □, R
Next 0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back home
1 → □, L
Cross off 1
…
0
0
…

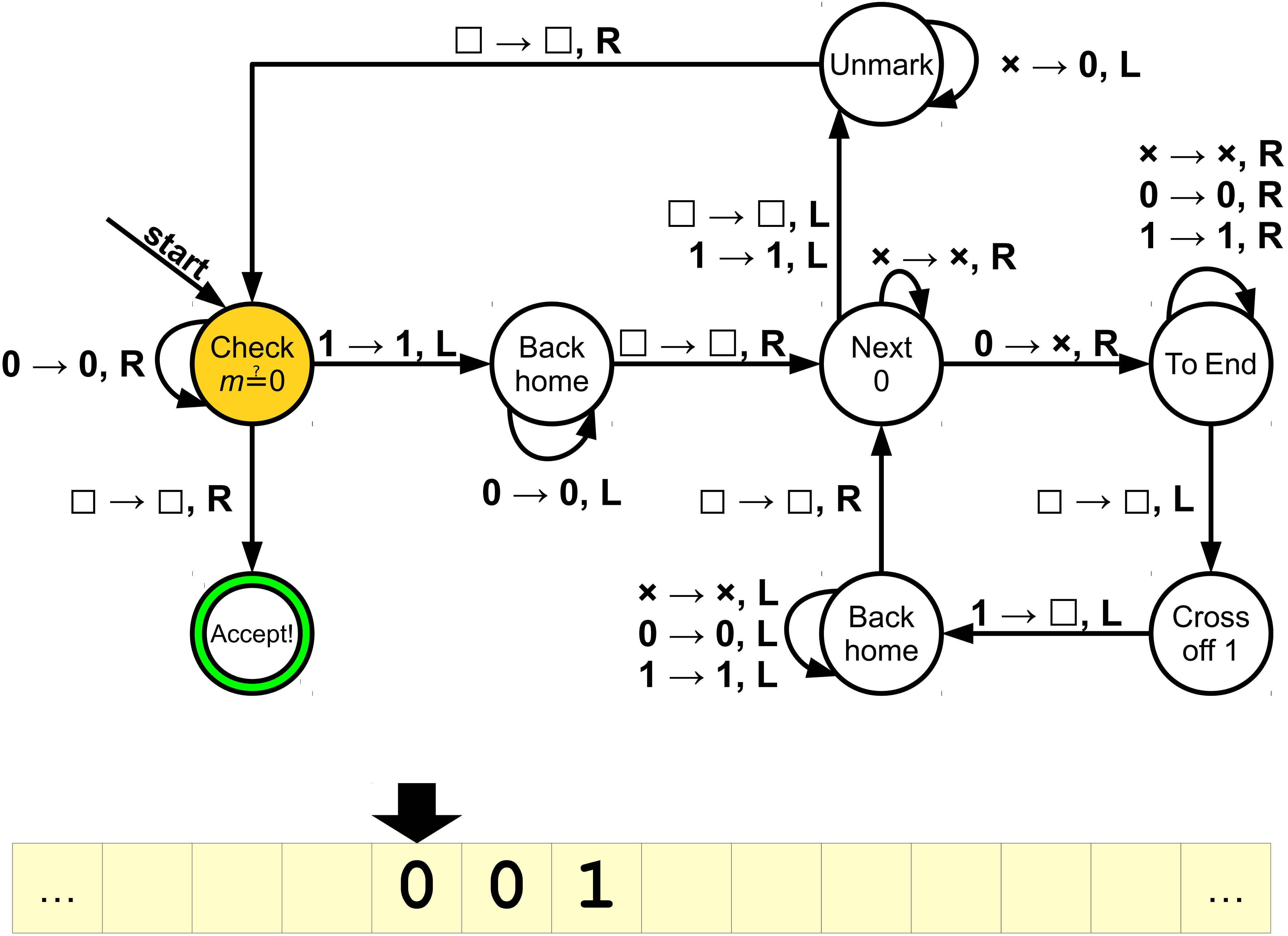

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
0
0
…

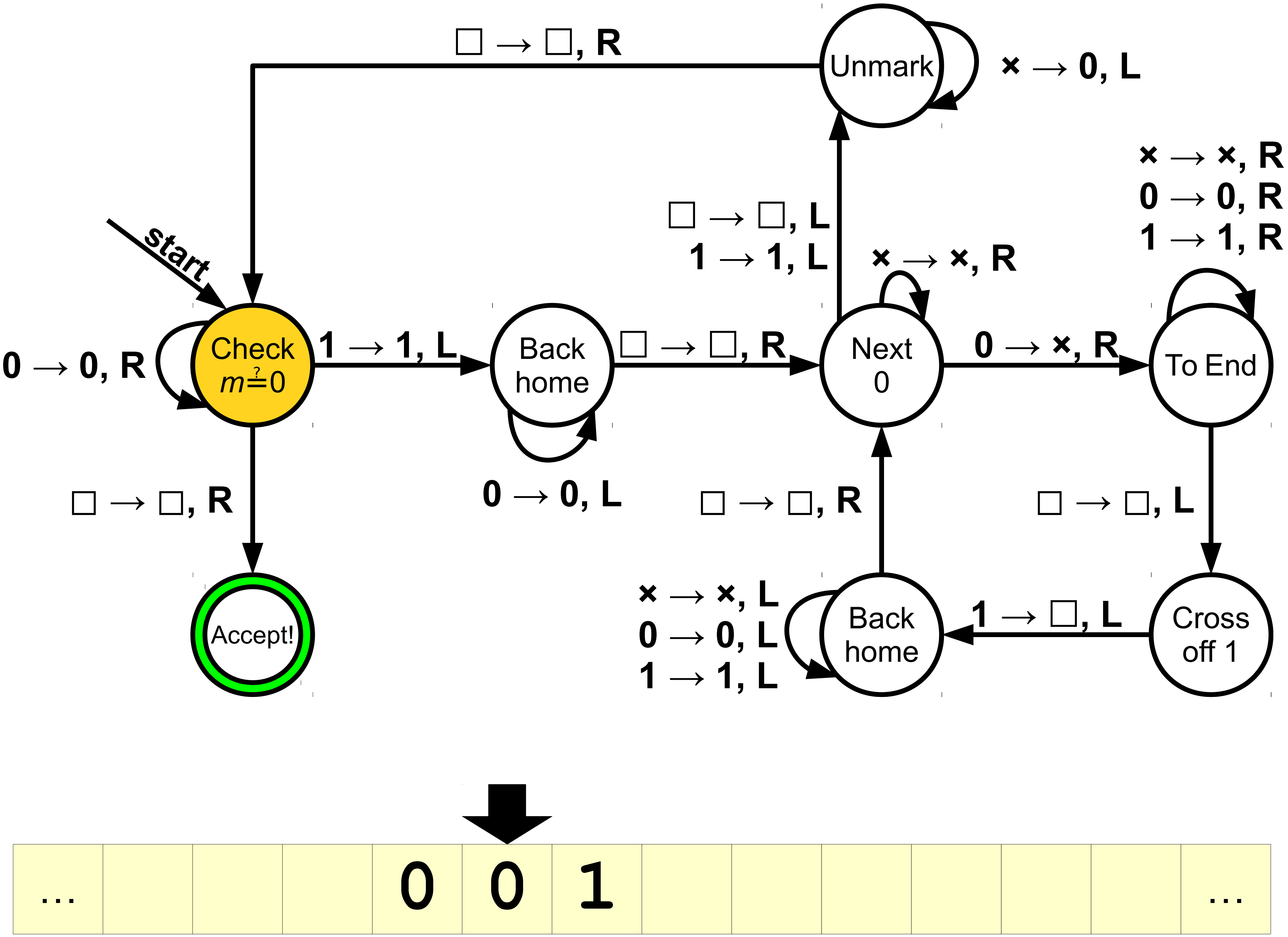

start
Check
m≟0
0 → 0, R
1 → 1, L
□ → □, R
Accept!
Back
home
0 → 0, L
□ → □, R
Next
0
× → ×, R
□ → □, L
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
0
0
…

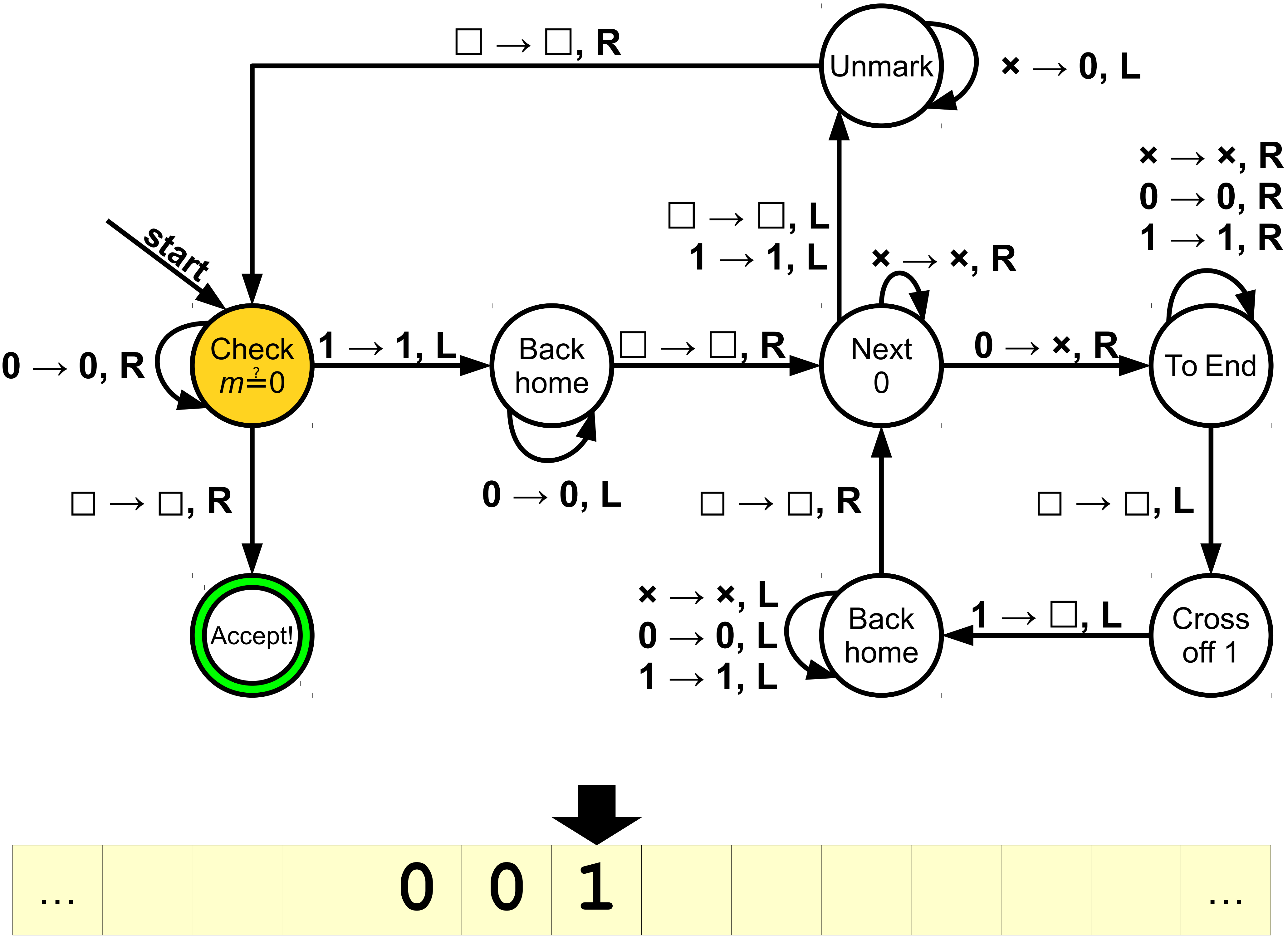

start
Check $m\overset{?}{=}0$
0 → 0, R
1 → 1, L
□ → □, R
Accept!
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
□ → □, L
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
0
0
…

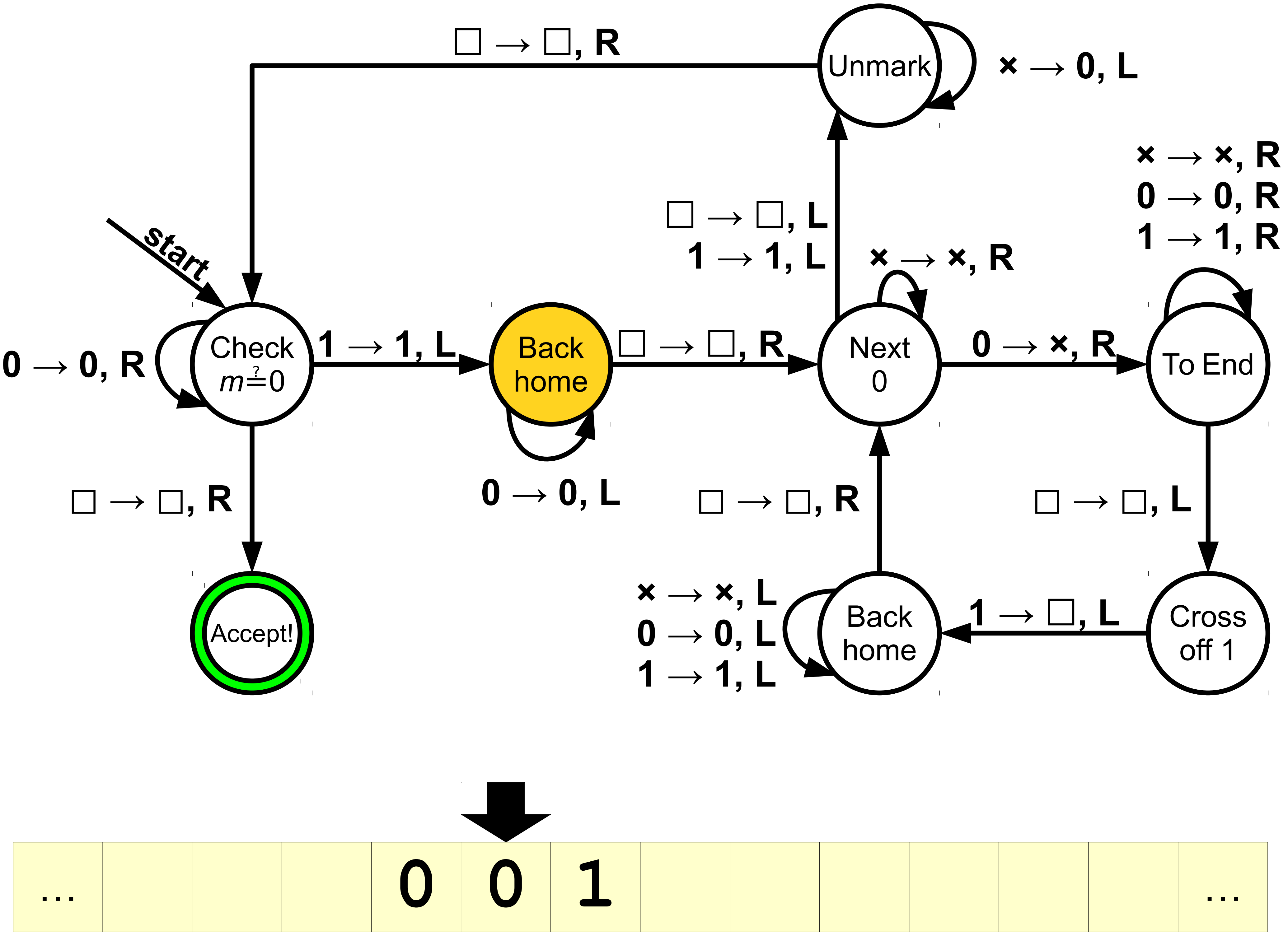

start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
□ → □, R
Accept!
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
□ → □, L
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
0
0
…

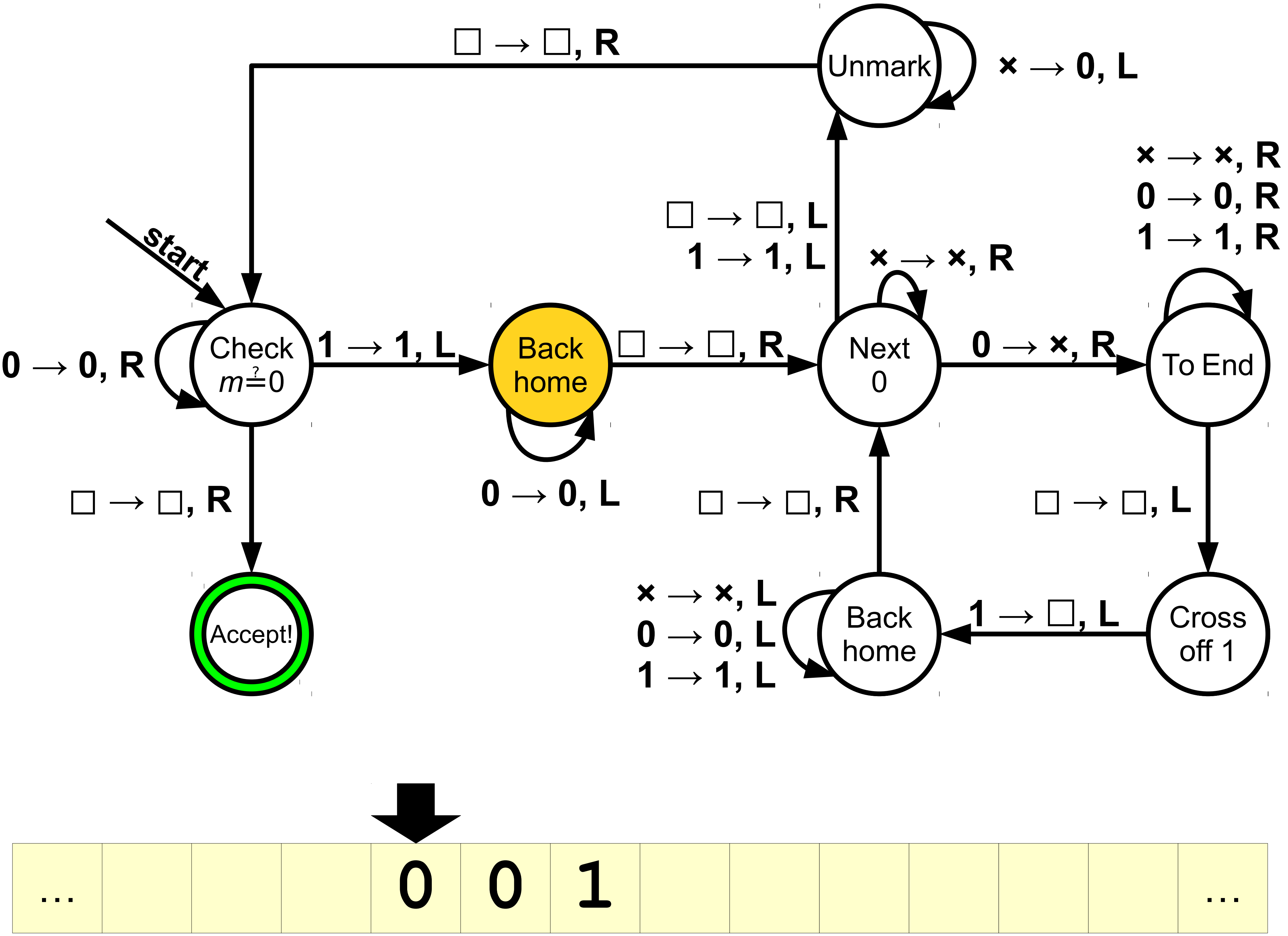

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
m ≟ 0
1 → 1, L
Back home
□ → □, R
Next 0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back home
1 → □, L
Cross off 1
…
0
0
1
…

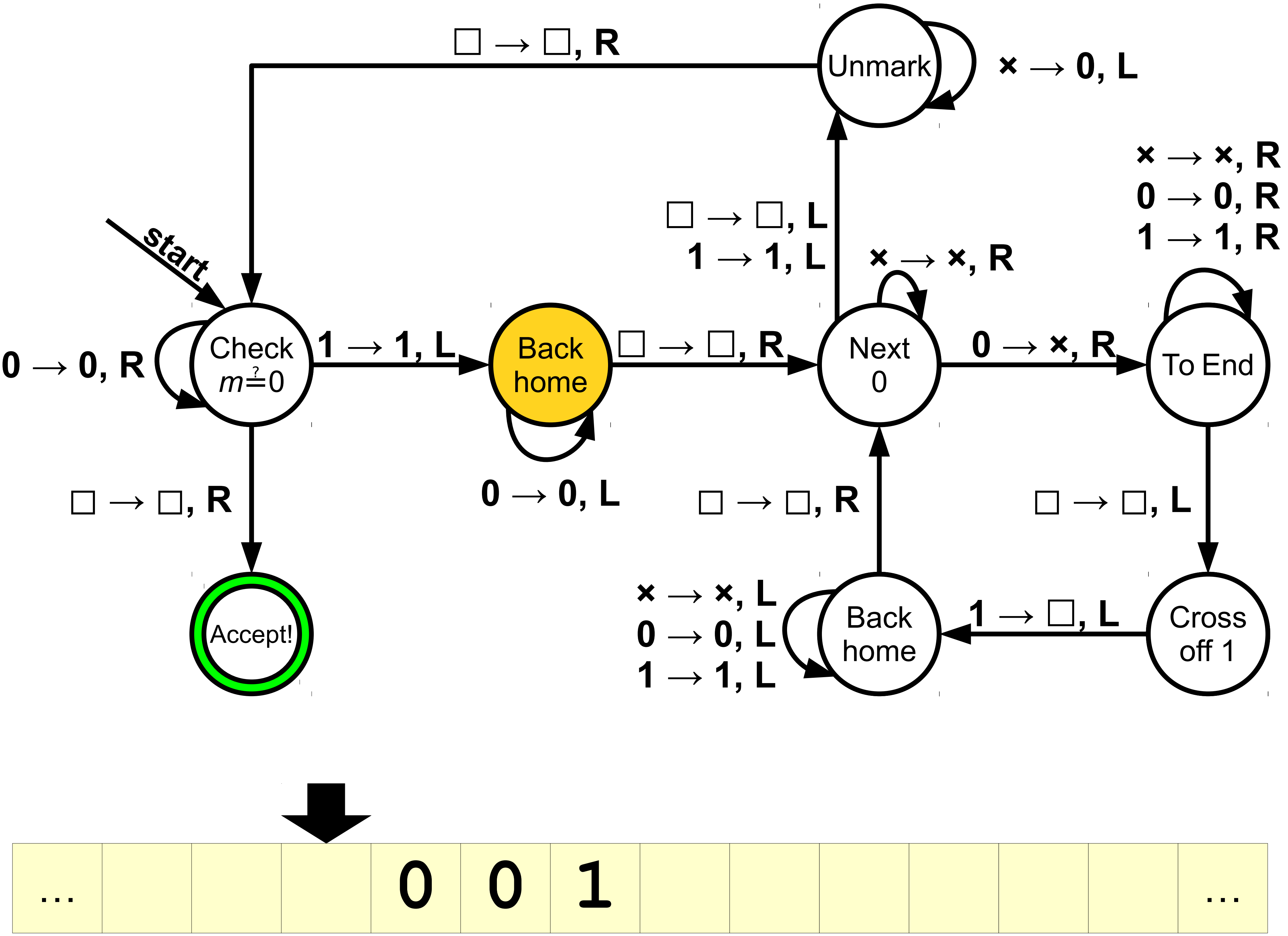

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
Check
$m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
Back home
□ → □, R
Next 0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back home
1 → □, L
Cross off 1
…
0
0
1
…

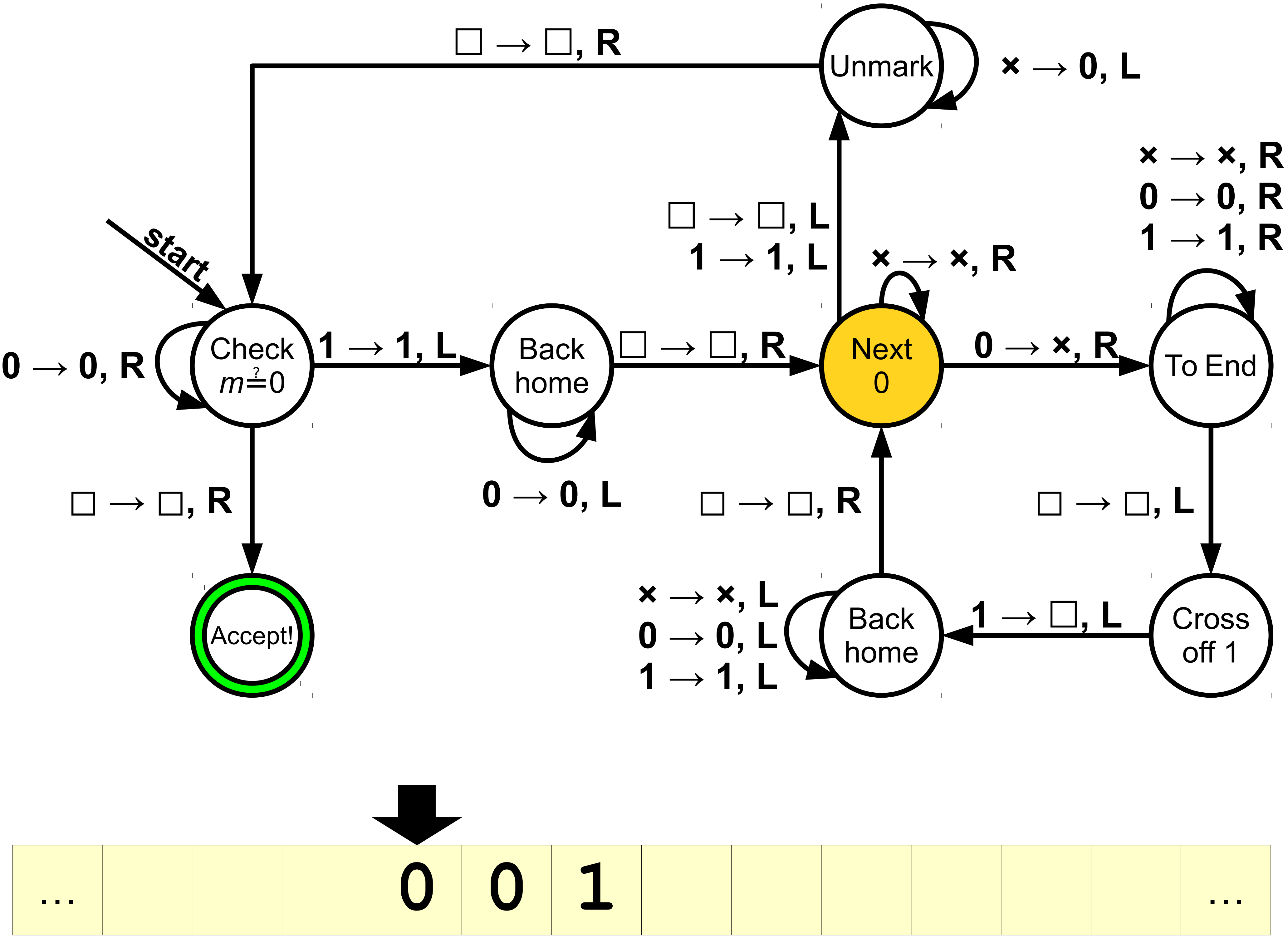

start
Check
$m\overset{?}{=}0$
0 → 0, R
1 → 1, L
□ → □, R
Accept!
Back
home
0 → 0, L
□ → □, R
Next
0
× → ×, R
□ → □, L
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
0
0
1
…

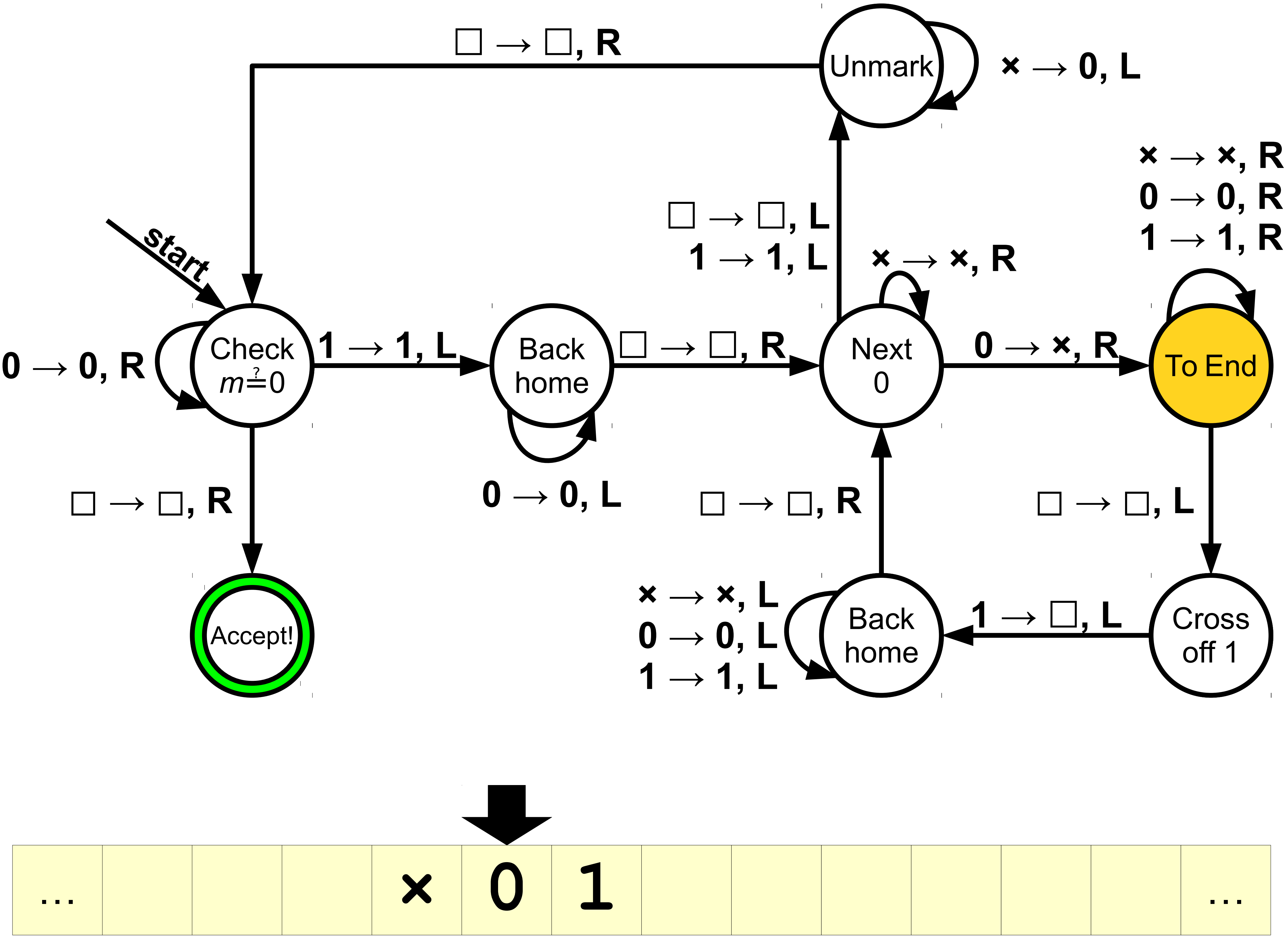

start
Check $m \overset{?}{=} 0$
0 → 0, R
□ → □, R
Accept!
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
□ → □, L
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
0
0
1
…

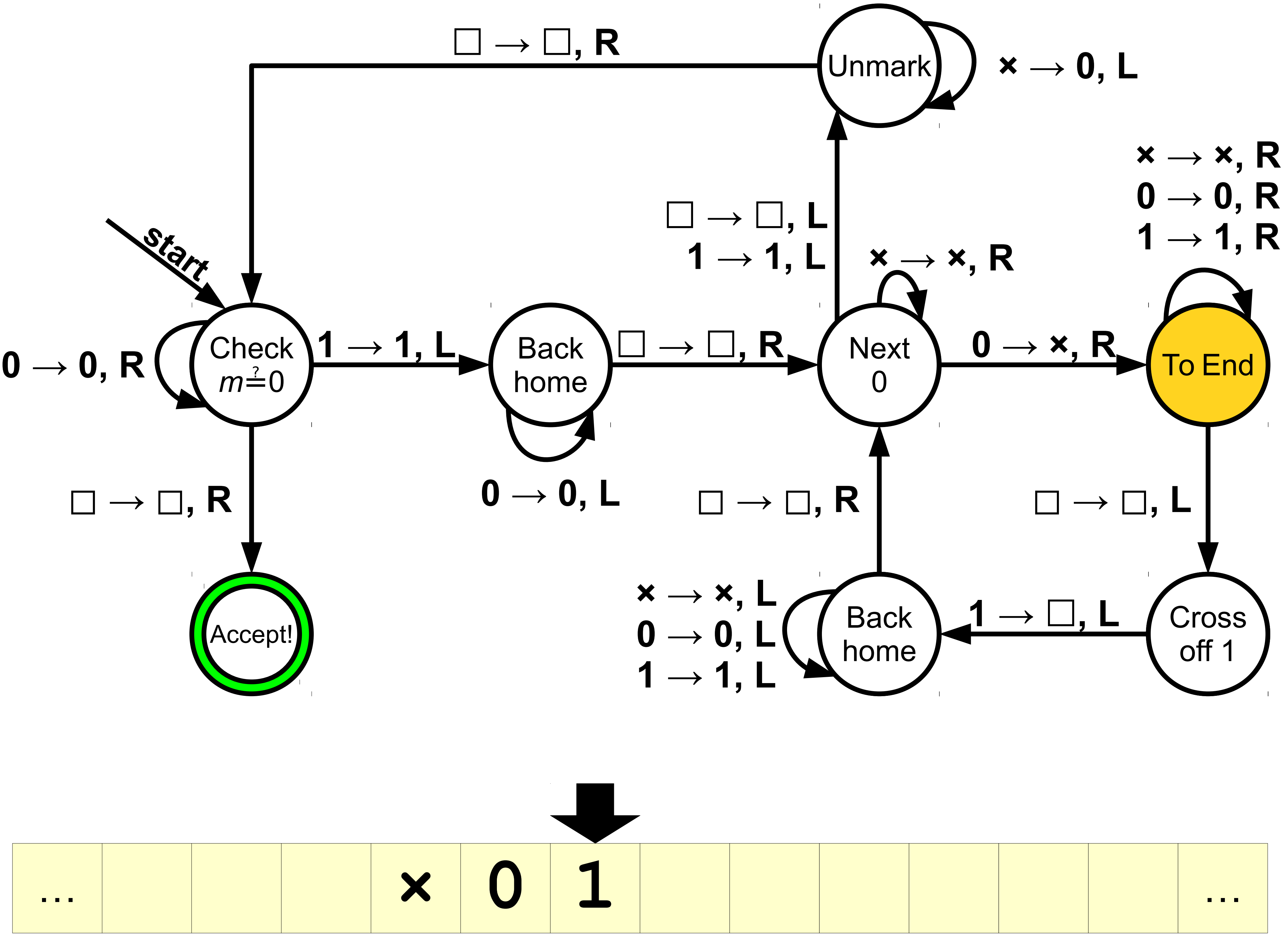

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
m ≟ 0
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
0
0
1
…

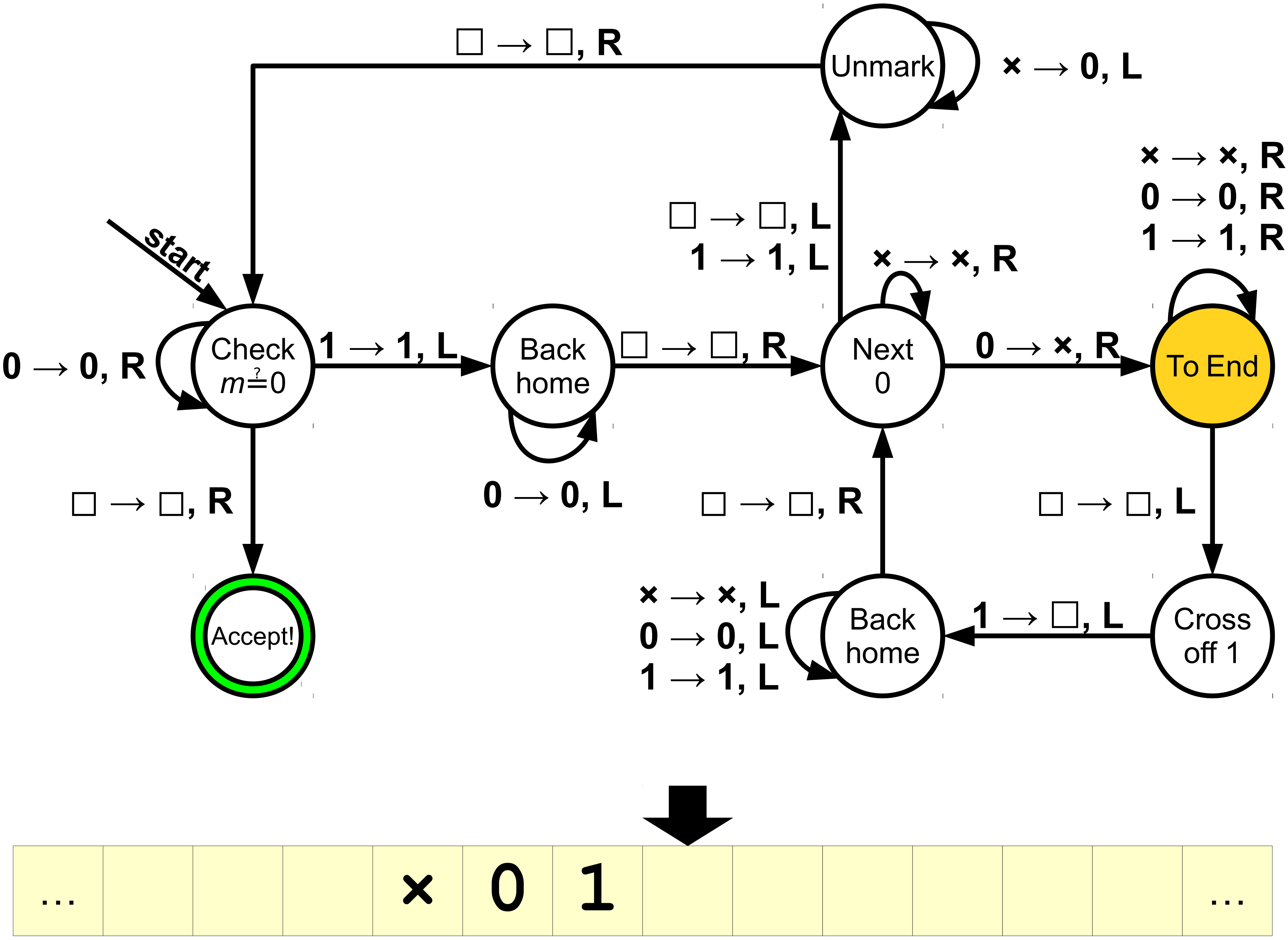

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back home
□ → □, R
Next 0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
□ → □, R
× → ×, L
0 → 0, L
1 → 1, L
Back home
1 → □, L
Cross off 1
Accept!
…
0
0
1
…

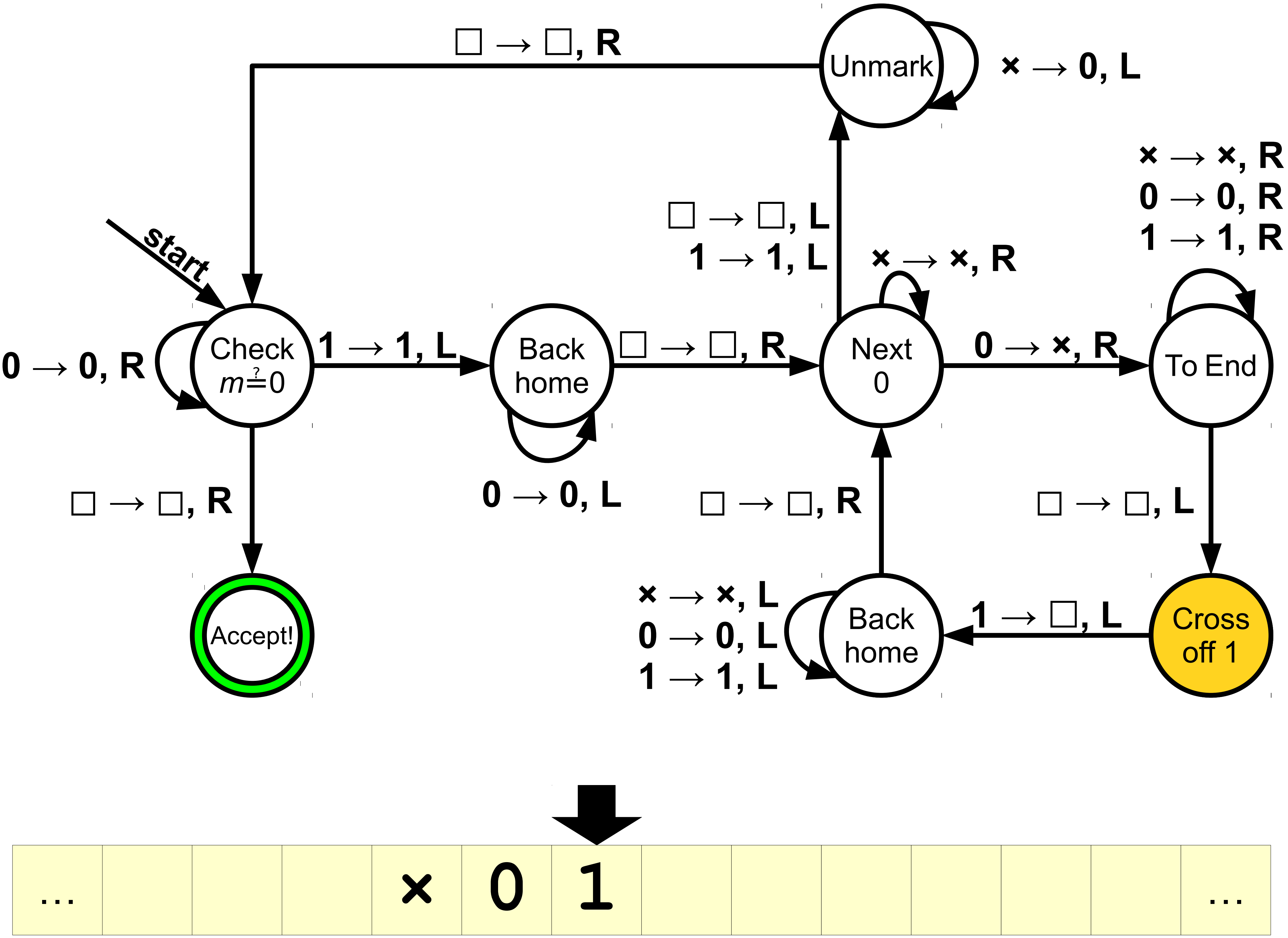

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
0
0
1
…

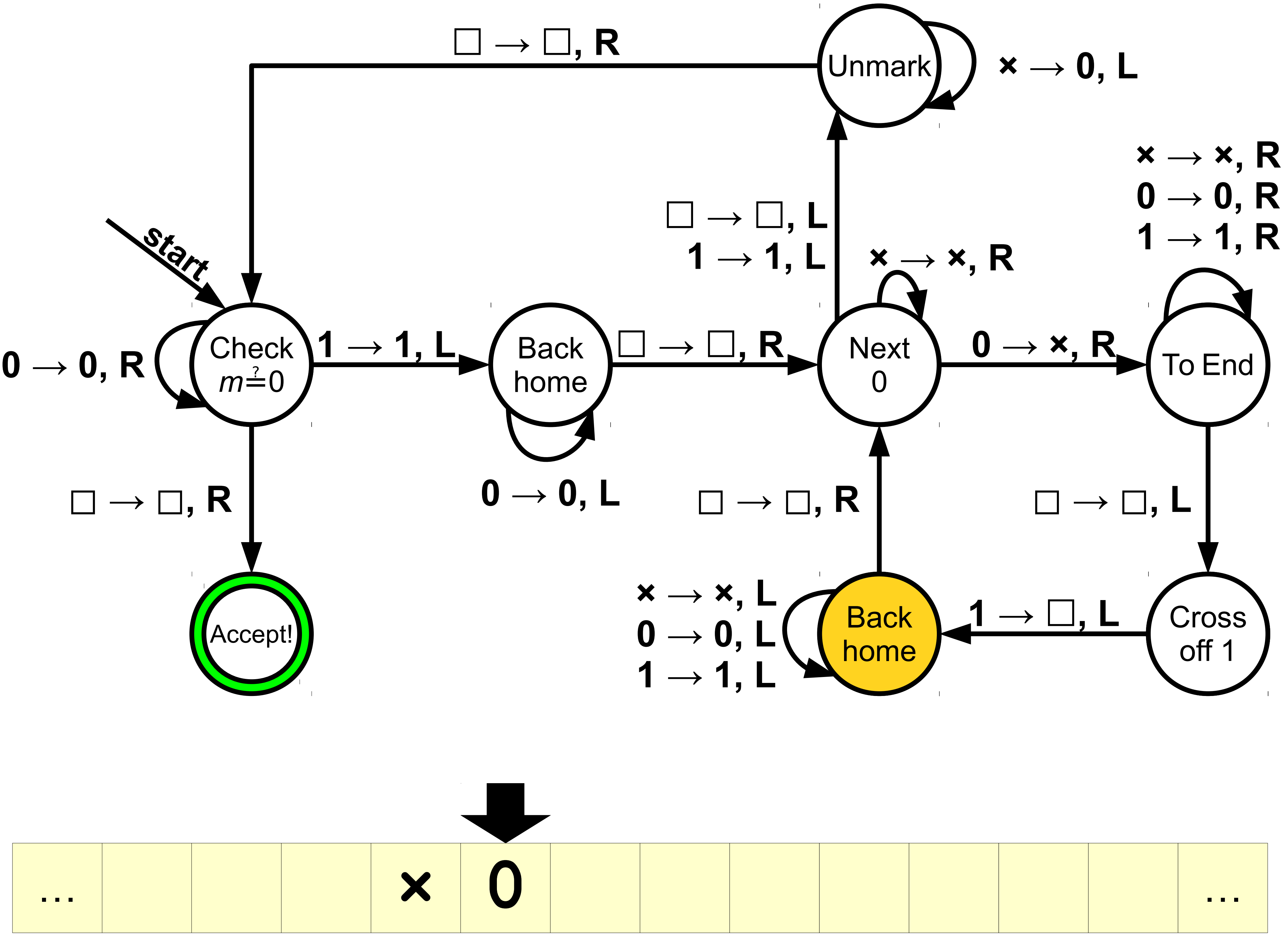

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
0
0
1
…

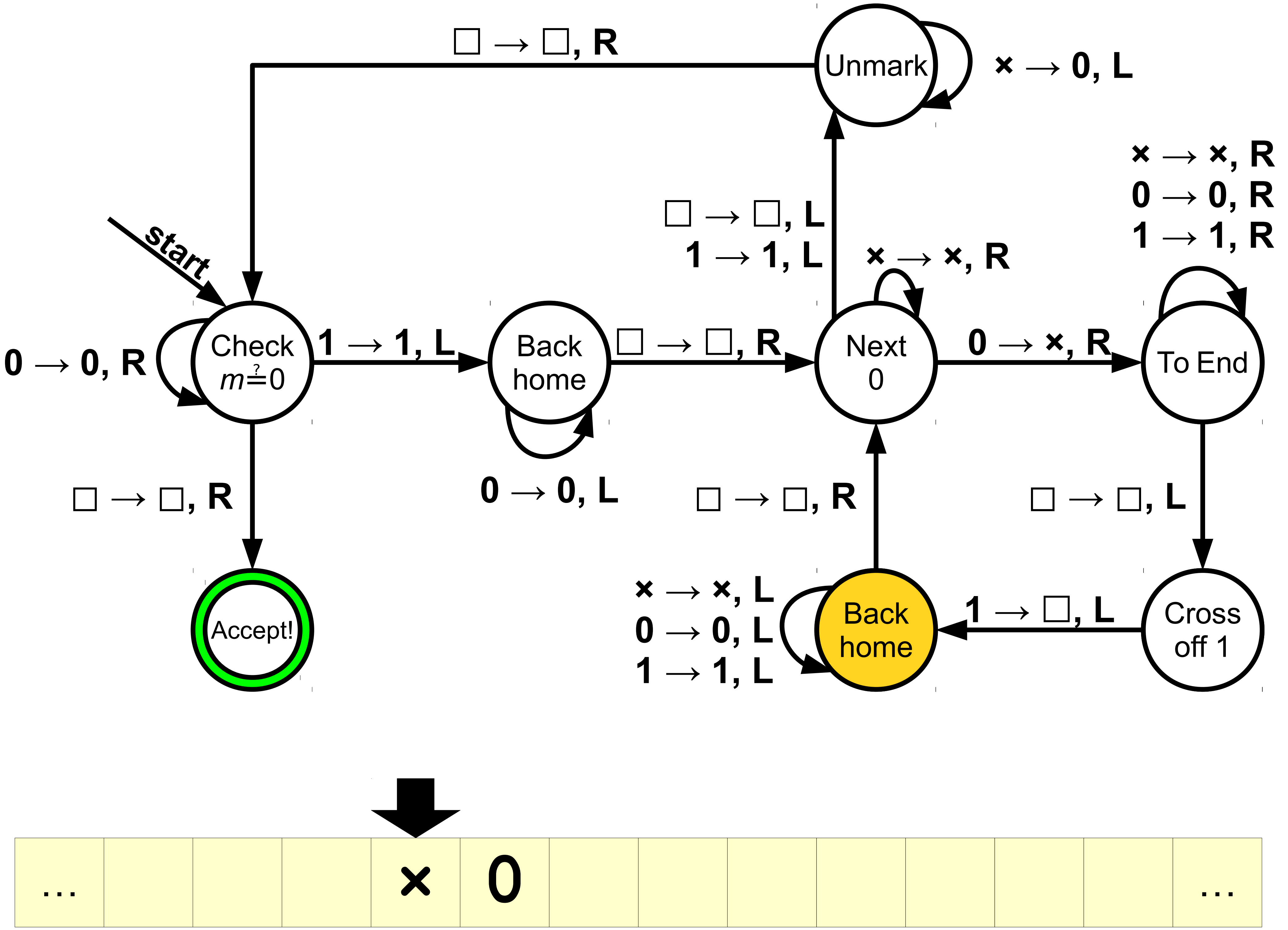

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
1
…

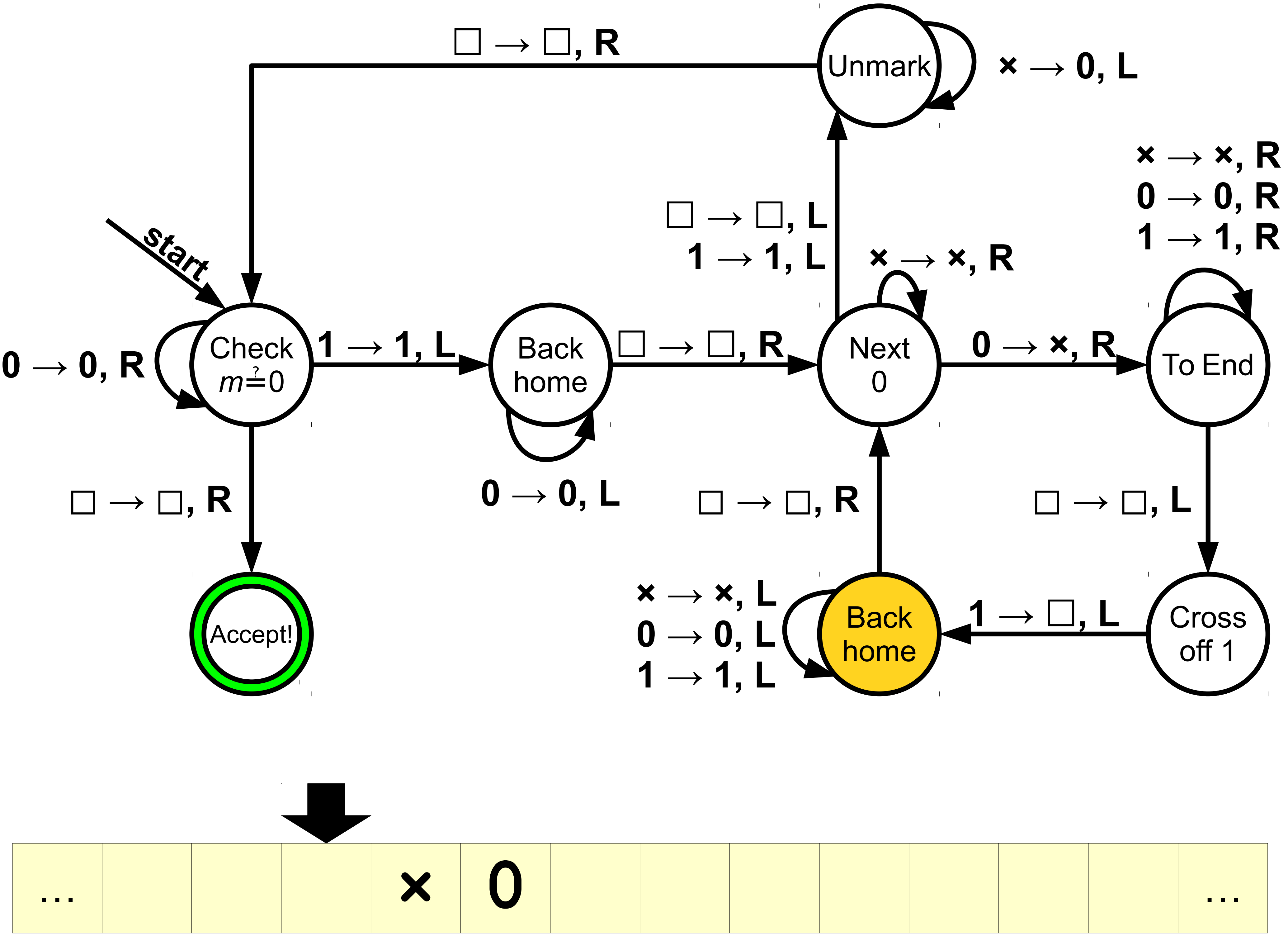

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
1
…

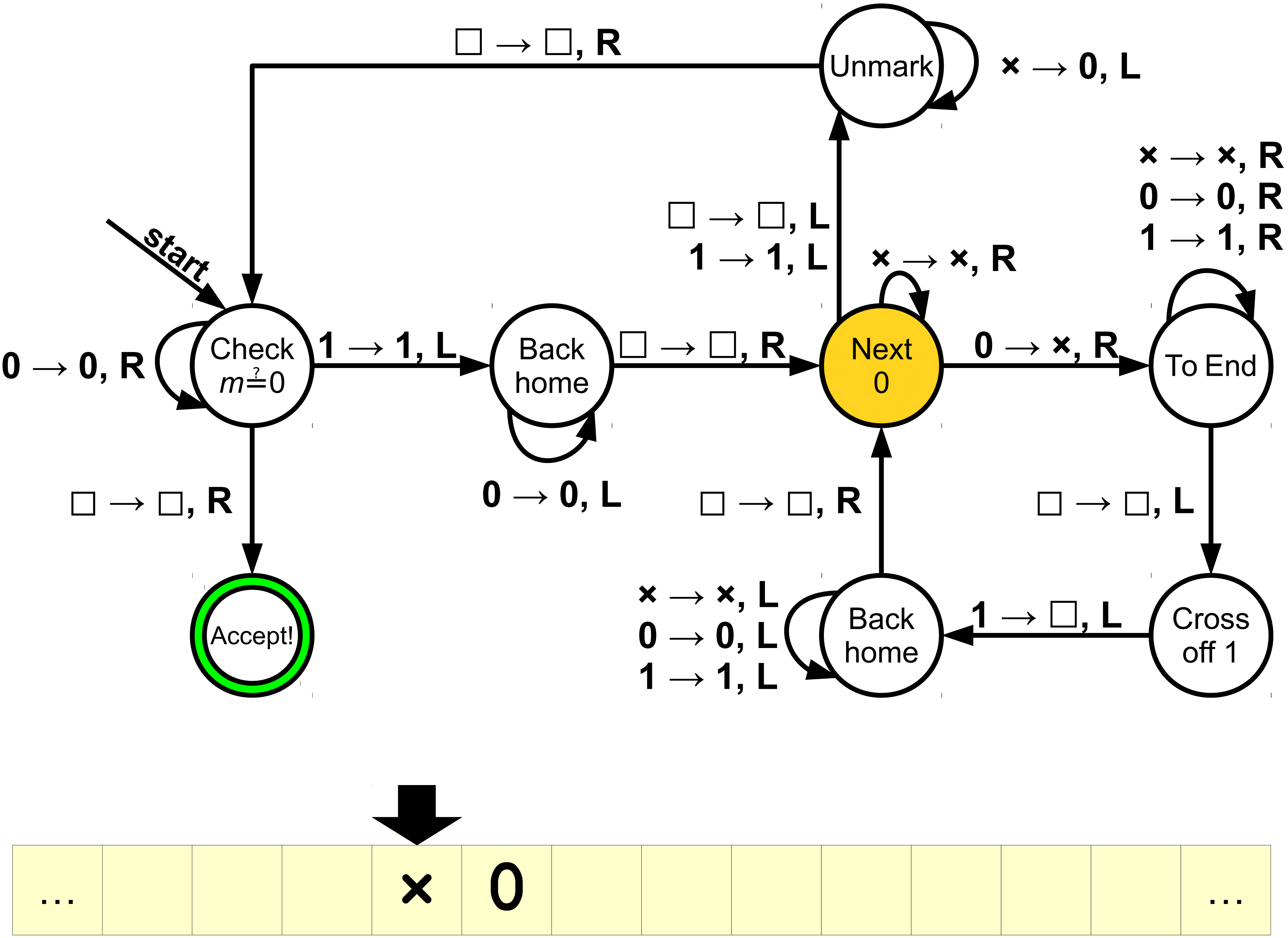

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
1
…

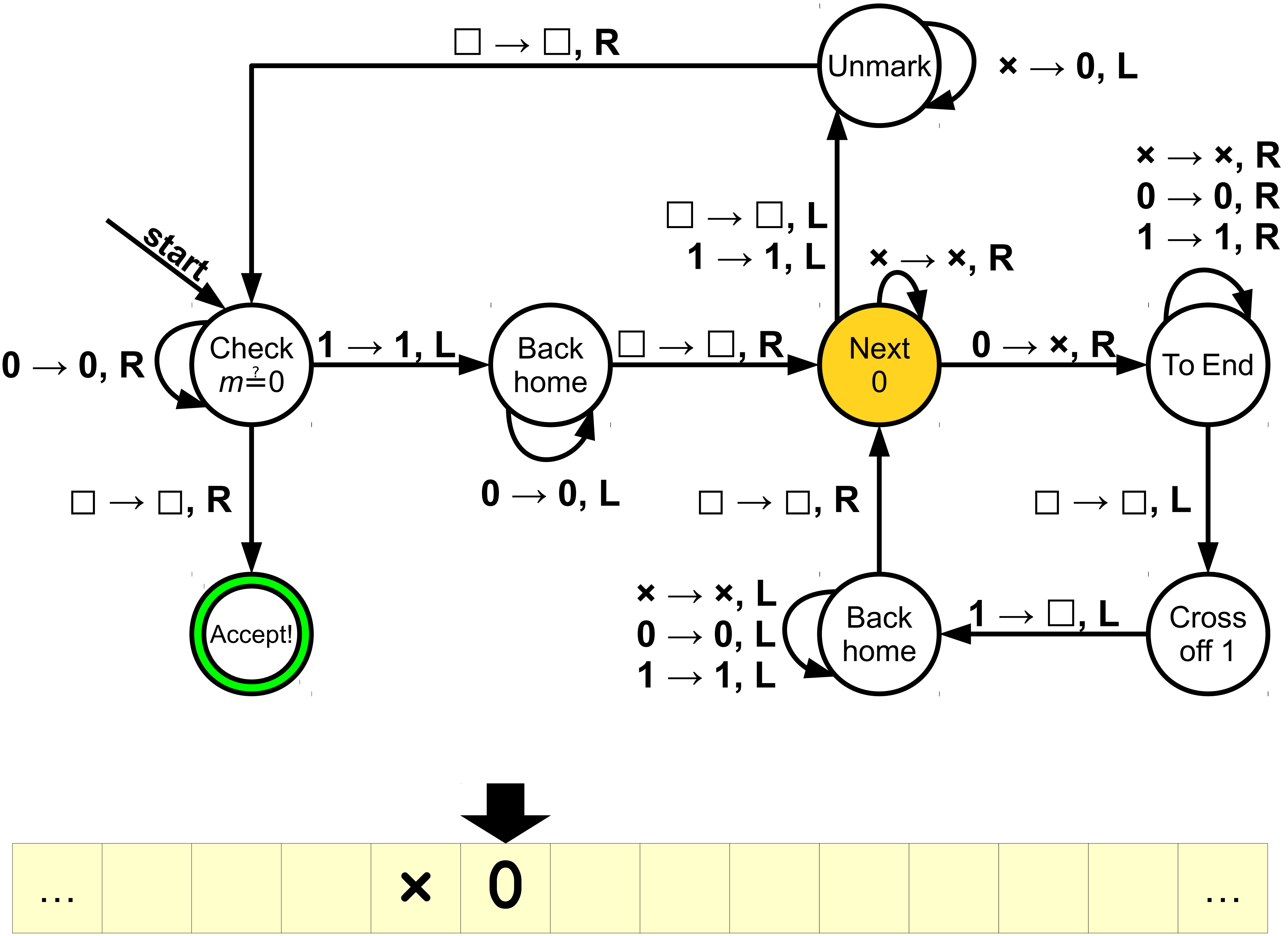

start
Check $m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
□ → □, R
Accept!
Back home
0 → 0, L
□ → □, R
Next 0
□ → □, L
1 → 1, L
× → ×, R
0 → ×, R
Unmark
× → 0, L
□ → □, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
0
1
…

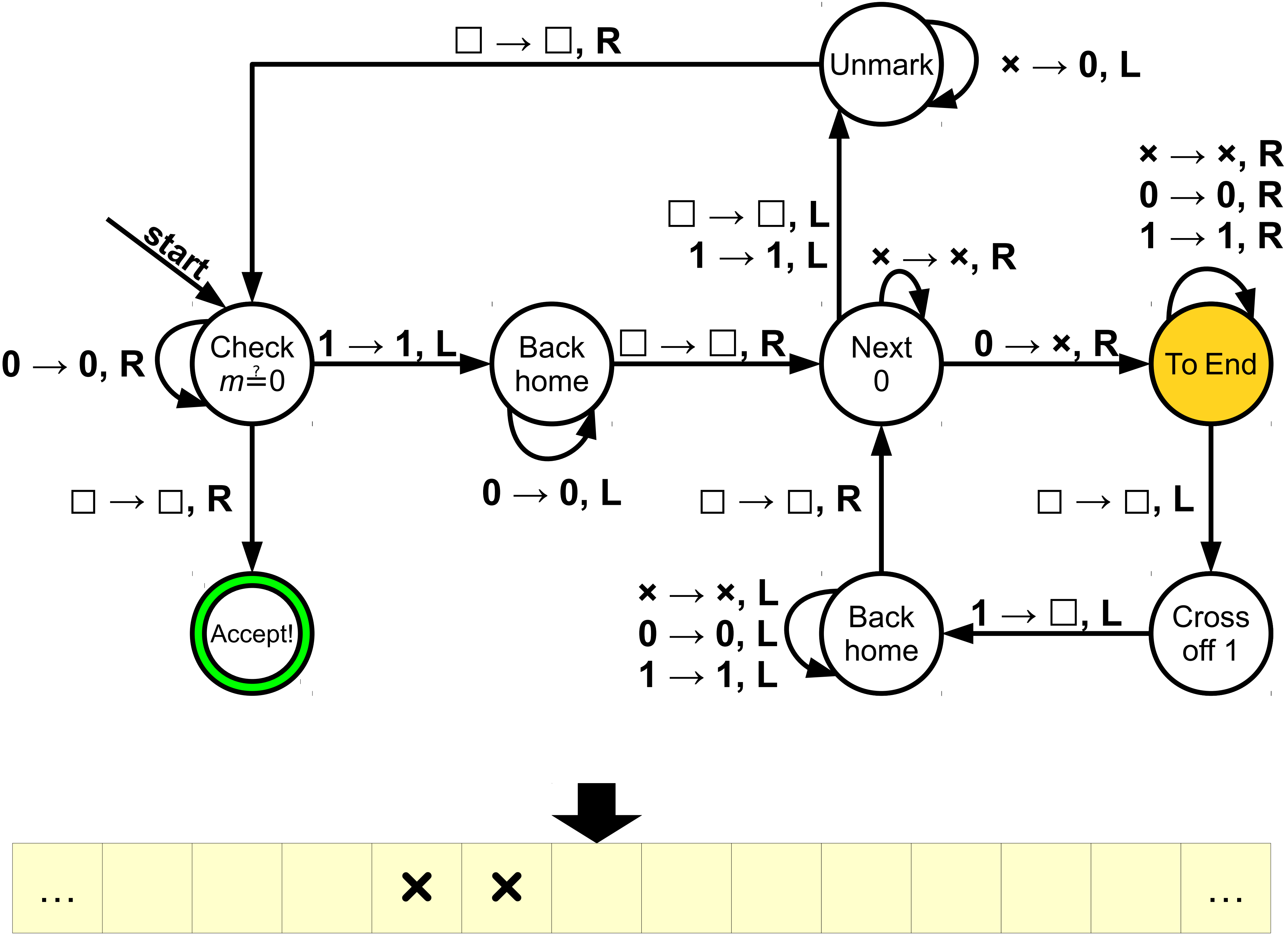

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
…

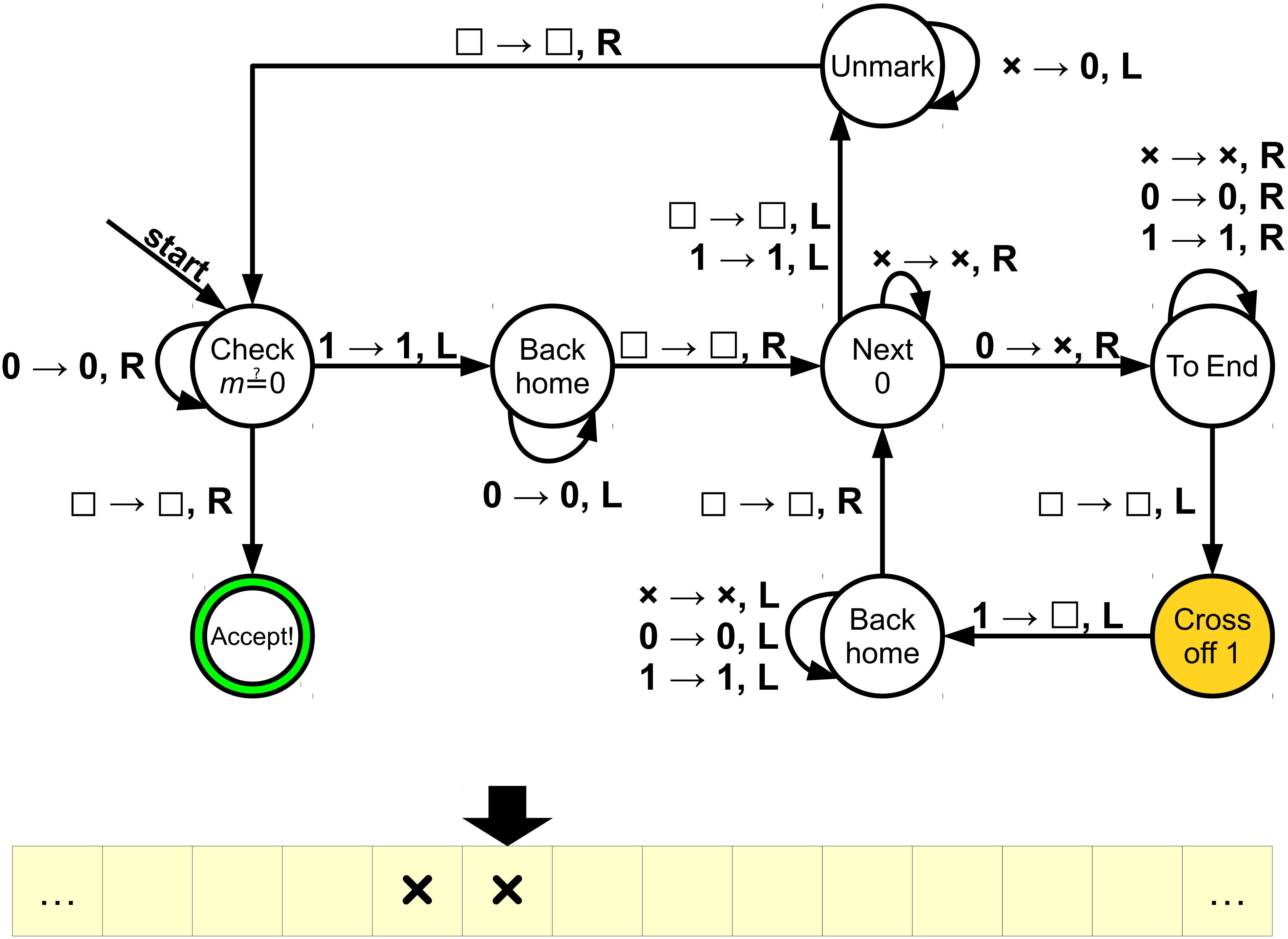

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back home
□ → □, R
Next 0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back home
1 → □, L
Cross off 1
Accept!
…
×
0
…

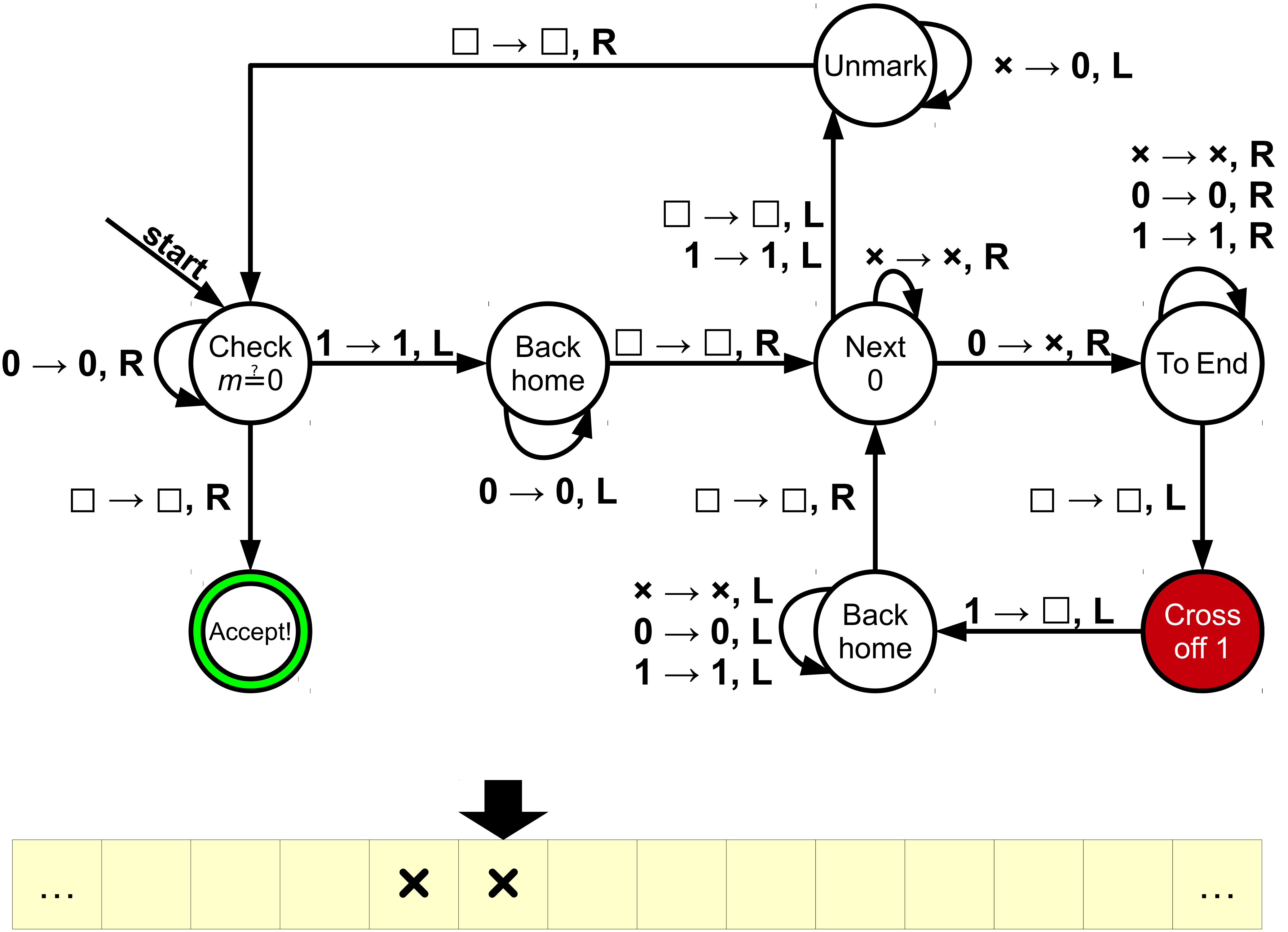

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
m ≟ 0
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
…

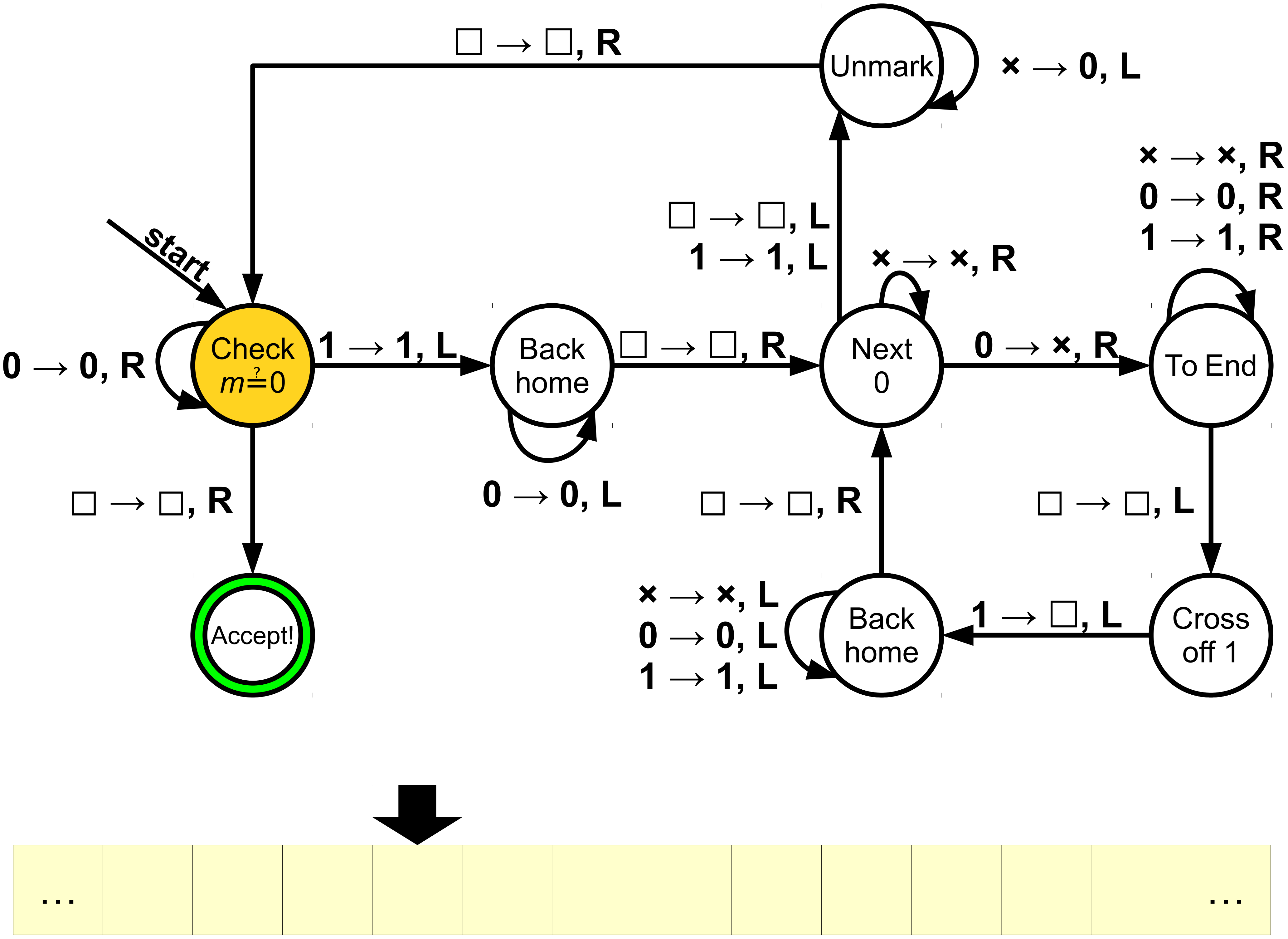

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
m≟0
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
□ → □, R
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
0
…

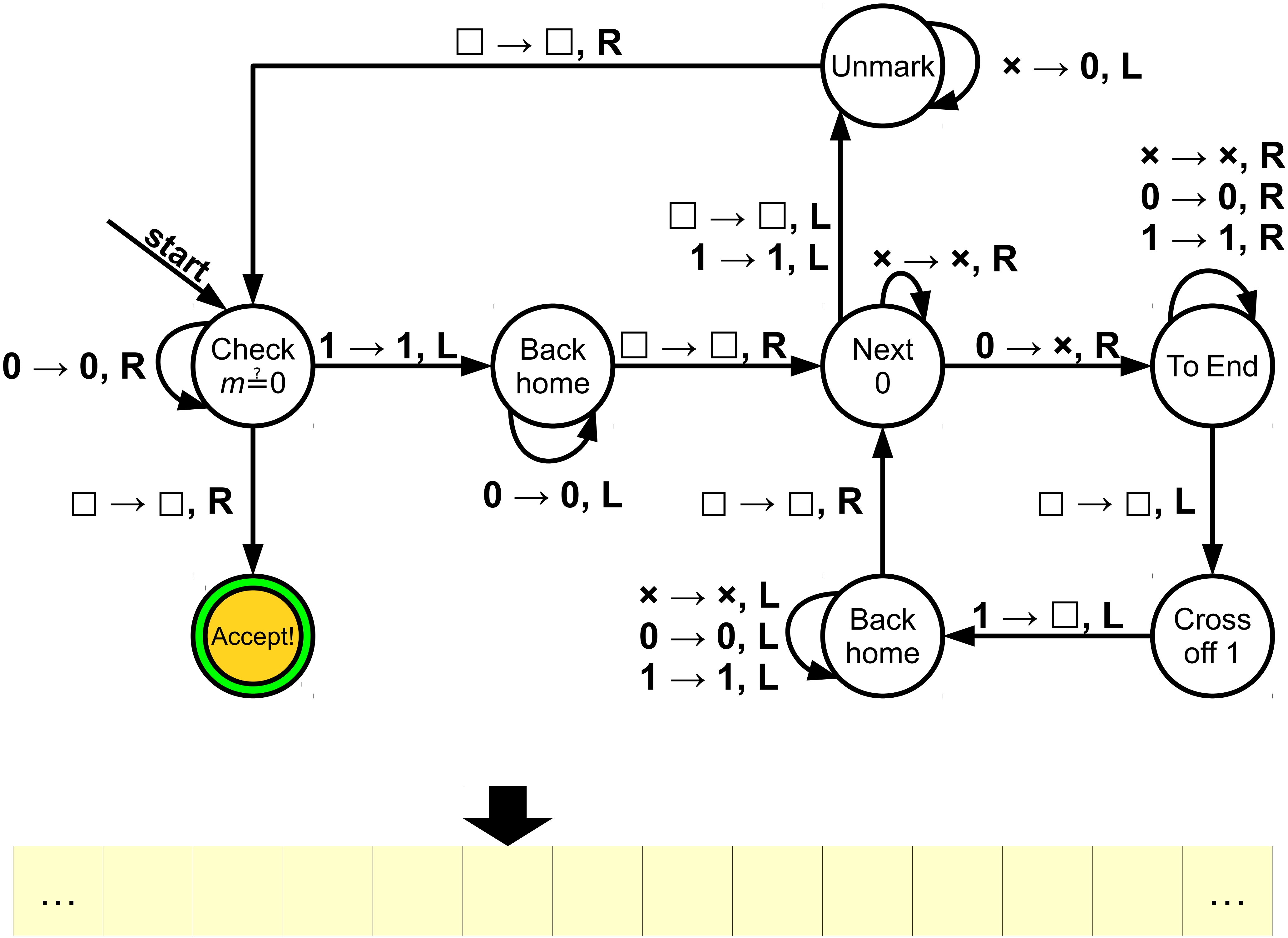

start
Check
$m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
□ → □, R
Accept!
Back
home
0 → 0, L
□ → □, R
Next
0
× → ×, R
□ → □, L
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross
off 1
1 → □, L
Back
home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
0
…

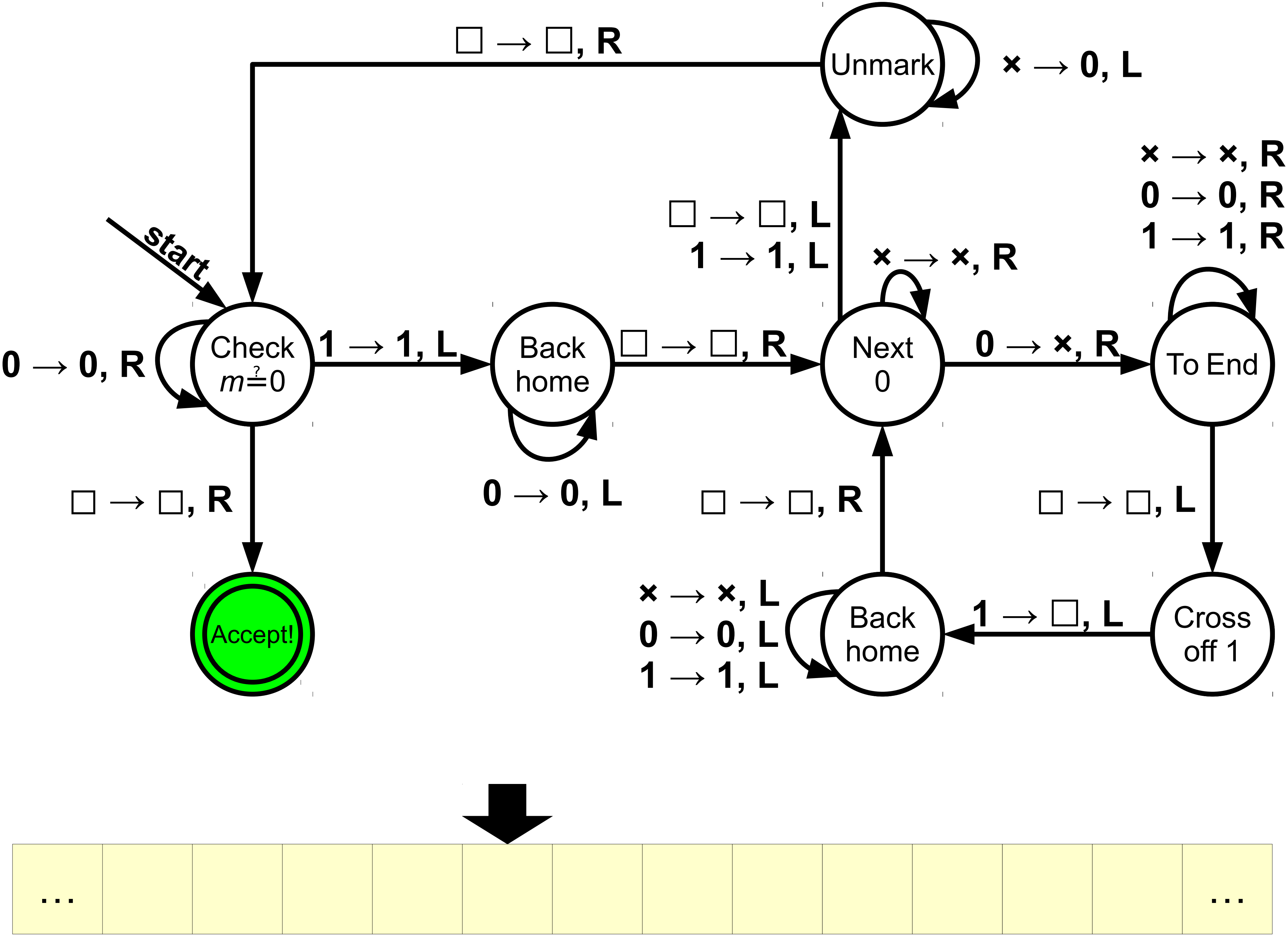

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
m≟0
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
×
×
…

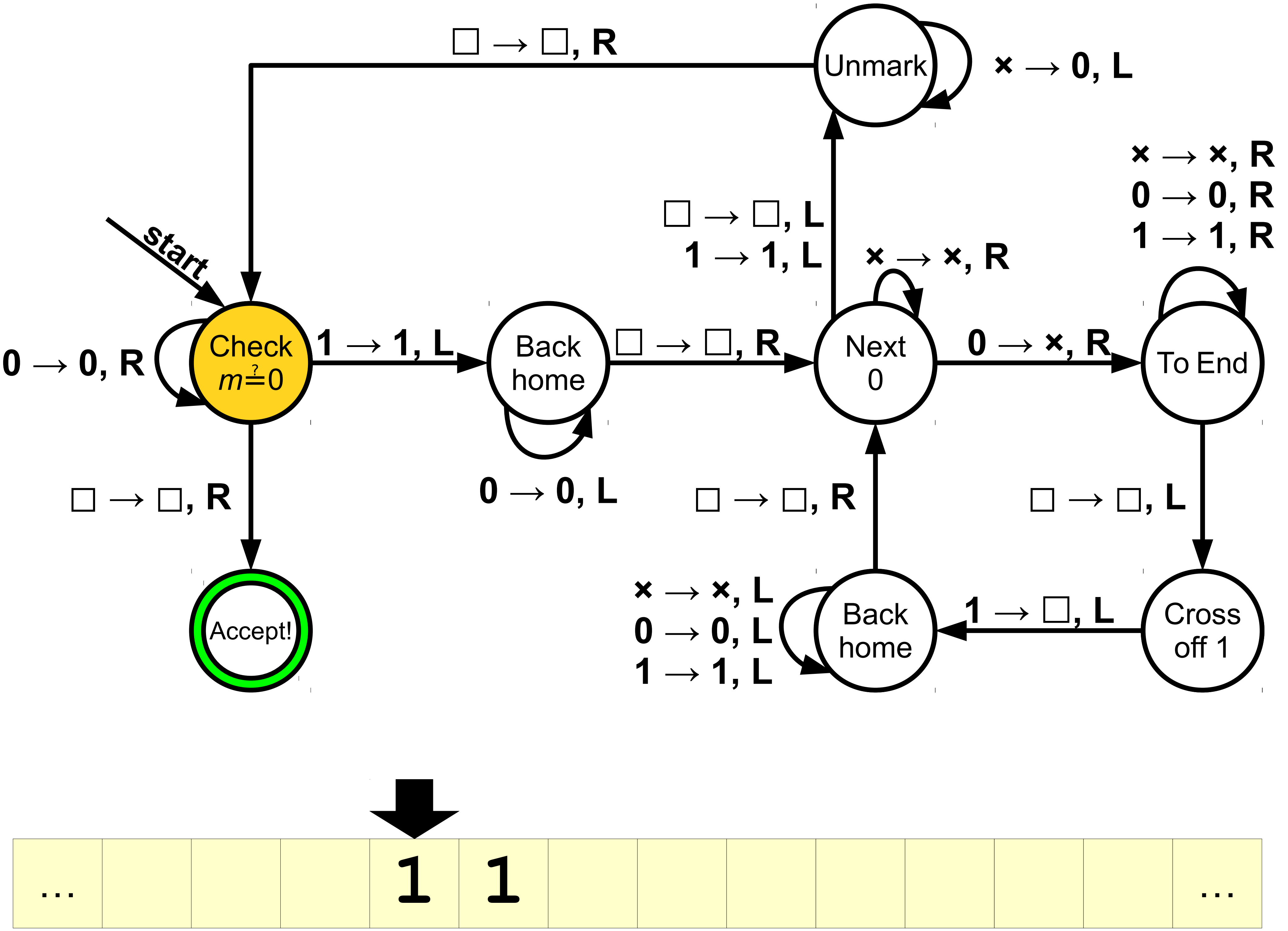

start
Check $m\overset{?}{=}0$
0 → 0, R
1 → 1, L
□ → □, R
Accept!
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
□ → □, L
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
×
×
…

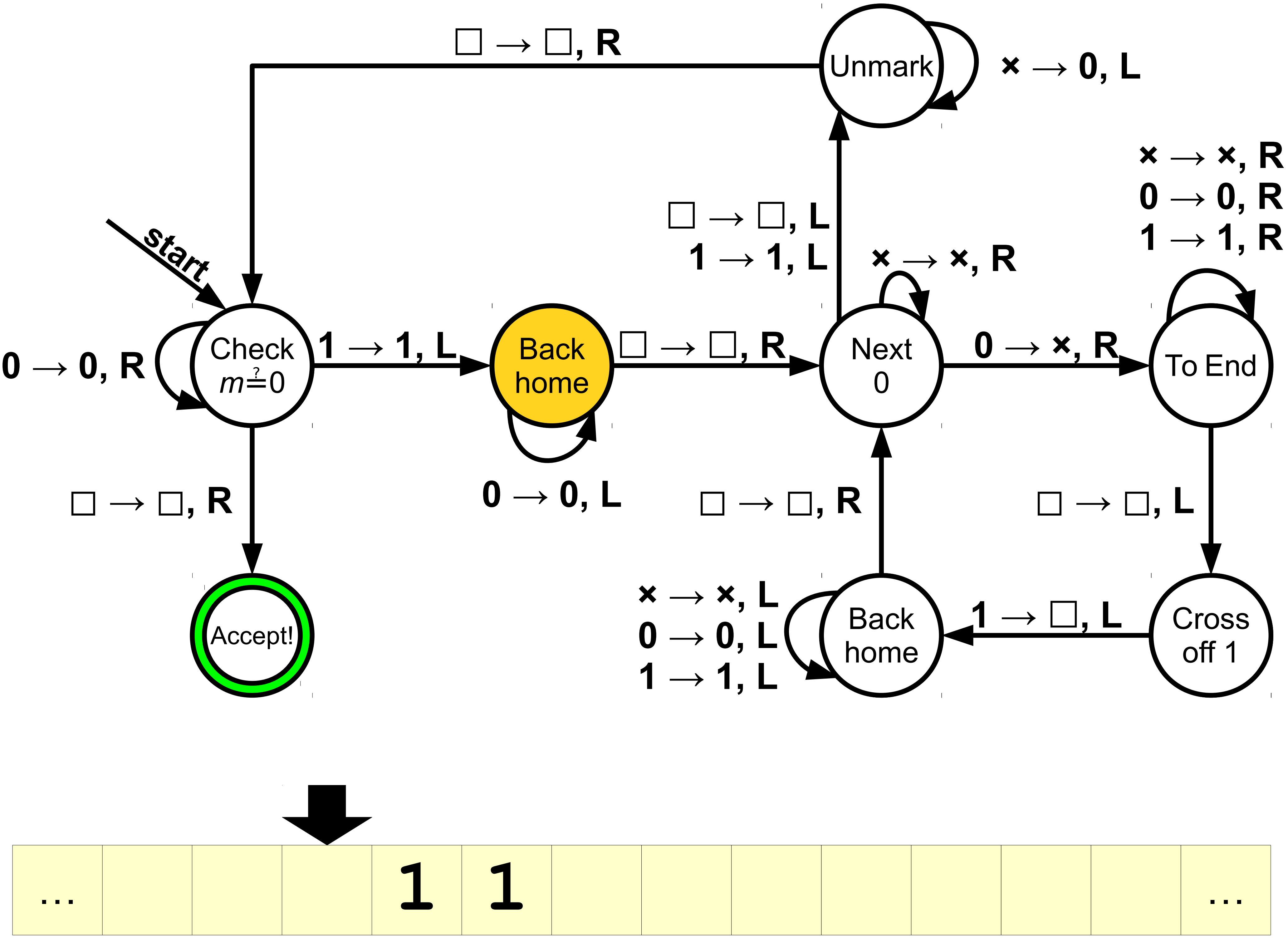

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back home
□ → □, R
Next 0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back home
1 → □, L
Cross off 1
…
×
×
…

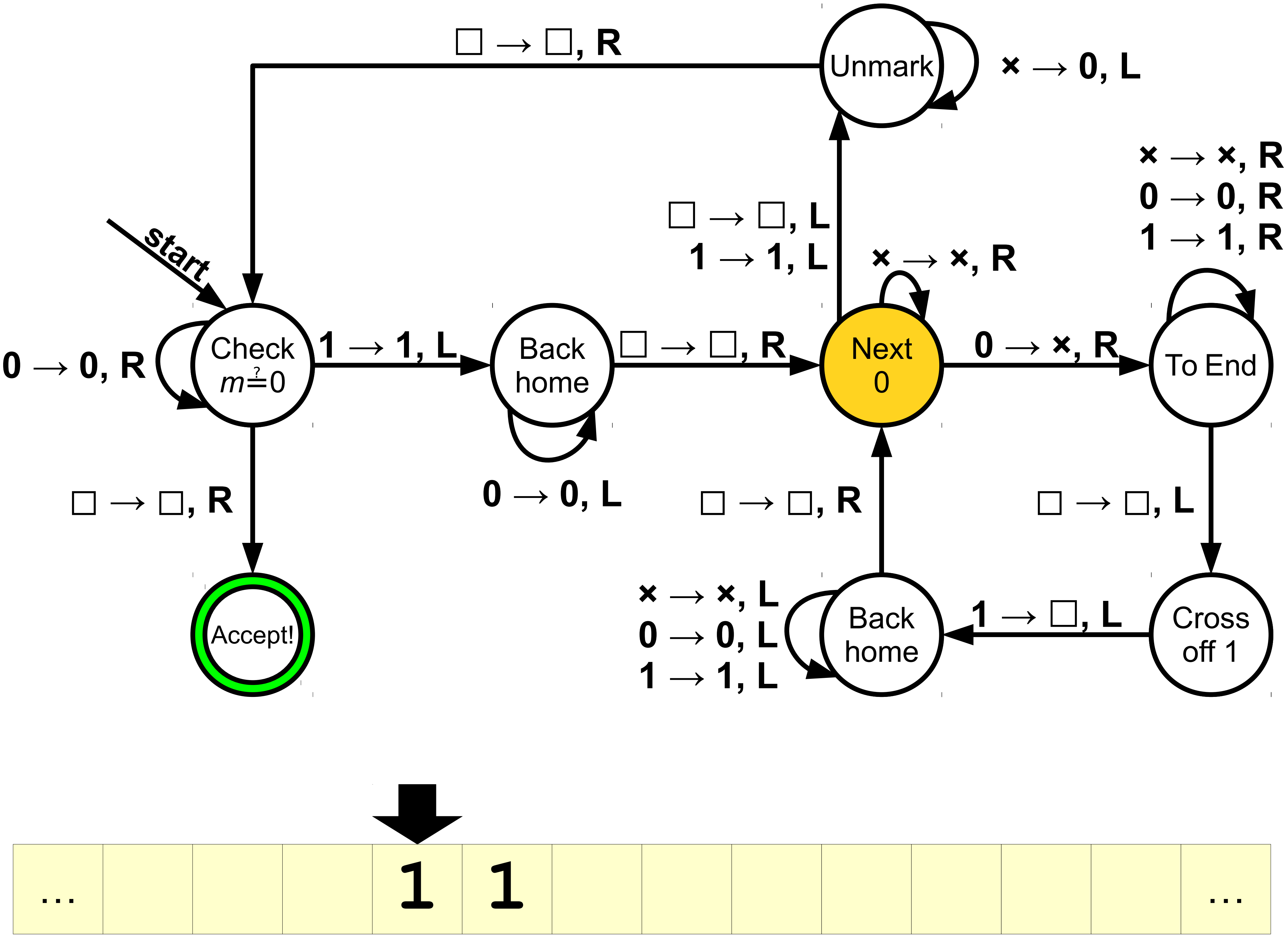

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back home
□ → □, R
Next 0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, L
□ → □, R
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back home
1 → □, L
Cross off 1
…
…


□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
m ≟ 0
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
…

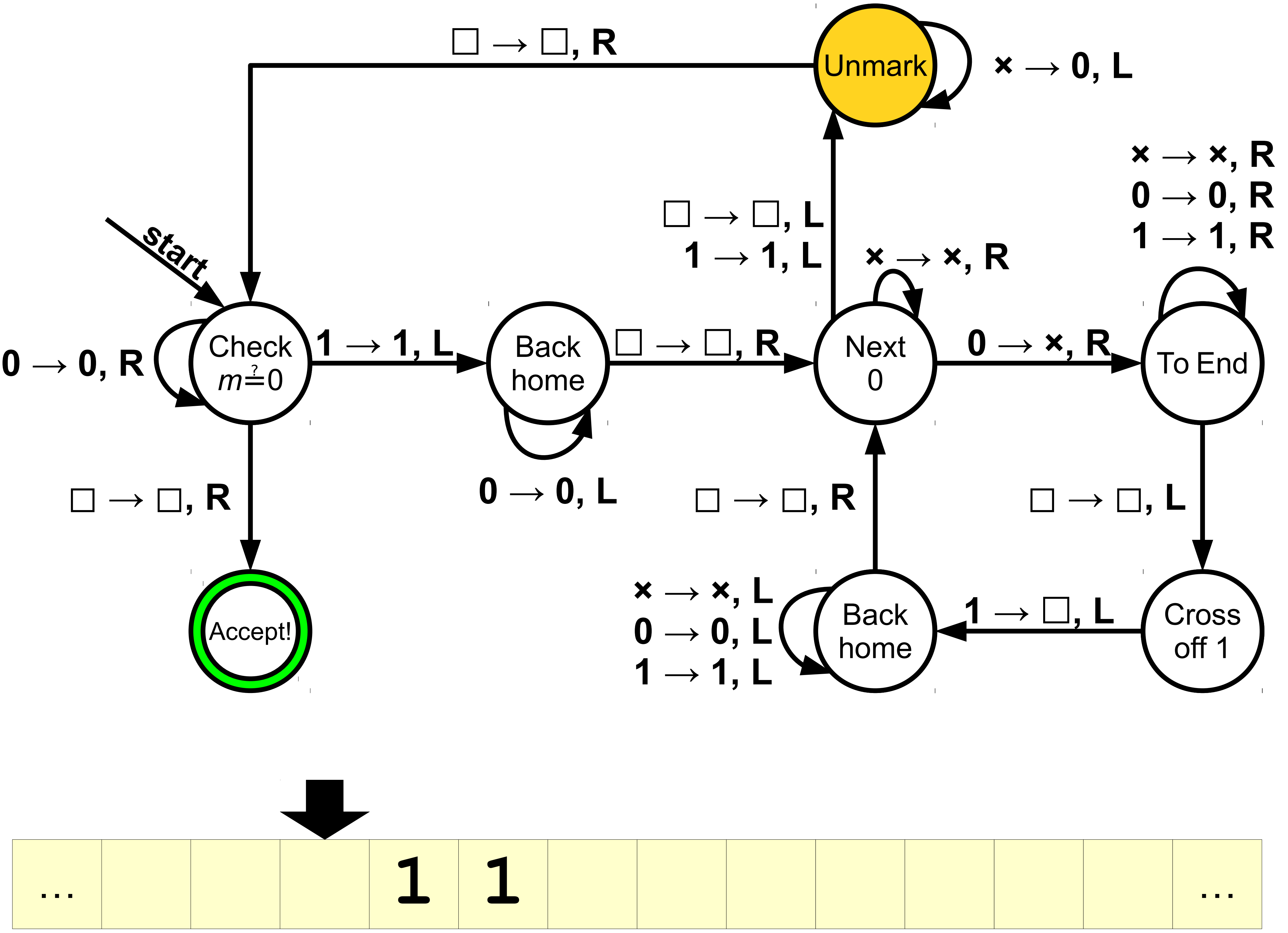

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
m ≟ 0
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
…

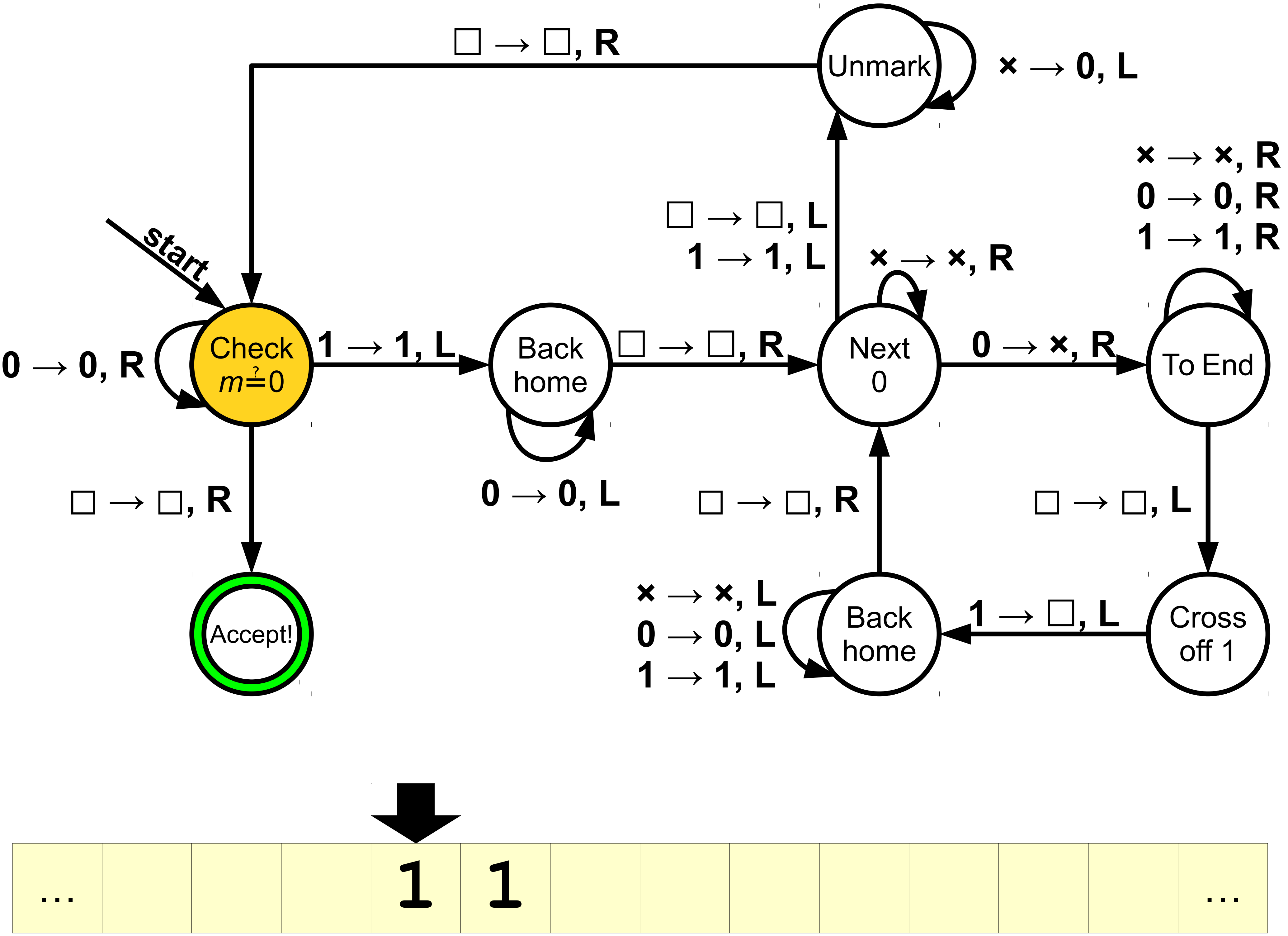

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
m ≟ 0
1 → 1, L
Back home
□ → □, R
Next 0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back home
1 → □, L
Cross off 1
…
1
1
…

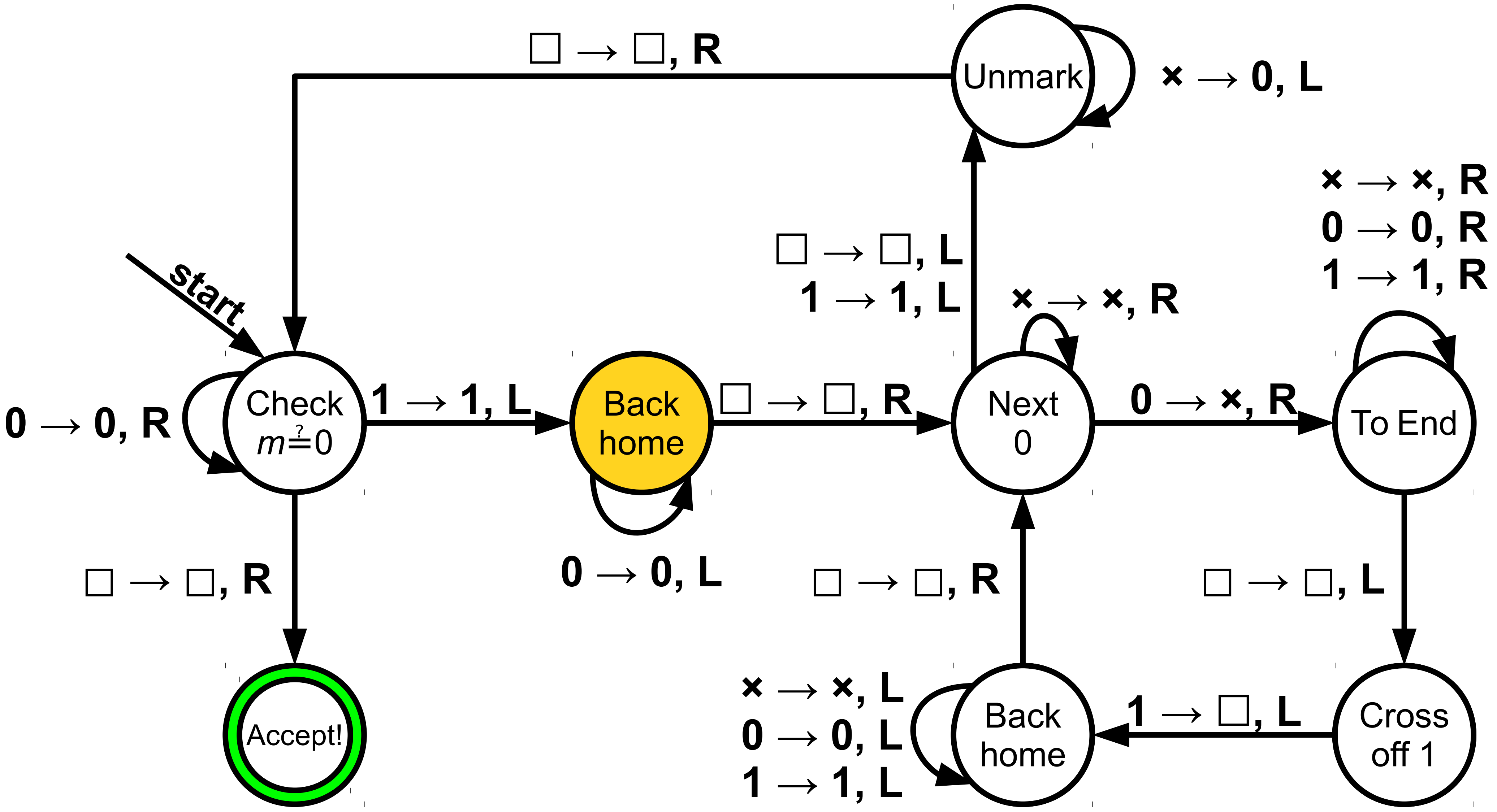

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
1
1
…



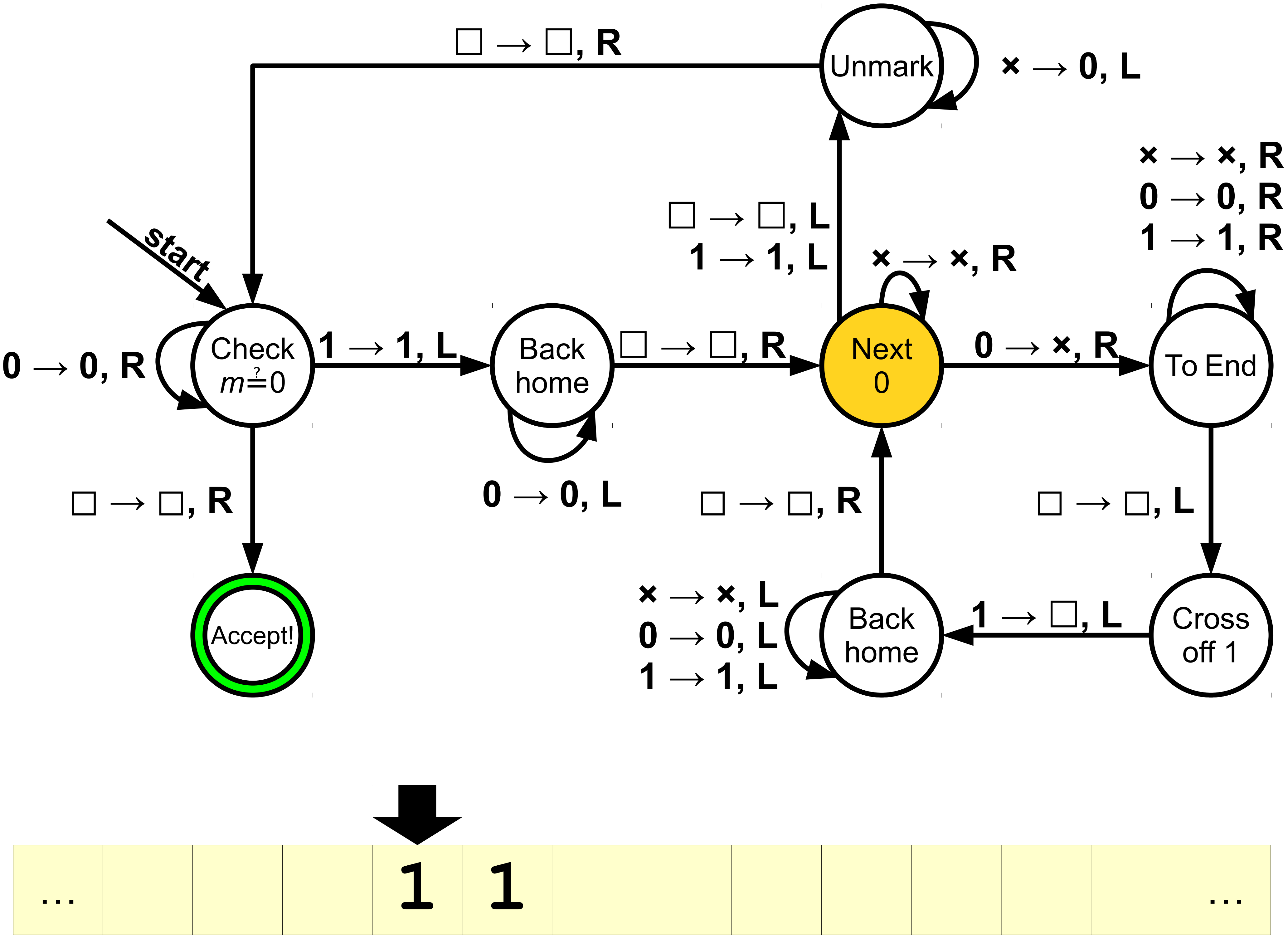
start
Check
$m \overset{?}{=} 0$
0 → 0, R
1 → 1, L
□ → □, R
Accept!
Back home
0 → 0, L
□ → □, R
Next 0
□ → □, L
1 → 1, L
× → ×, R
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
1
1
…

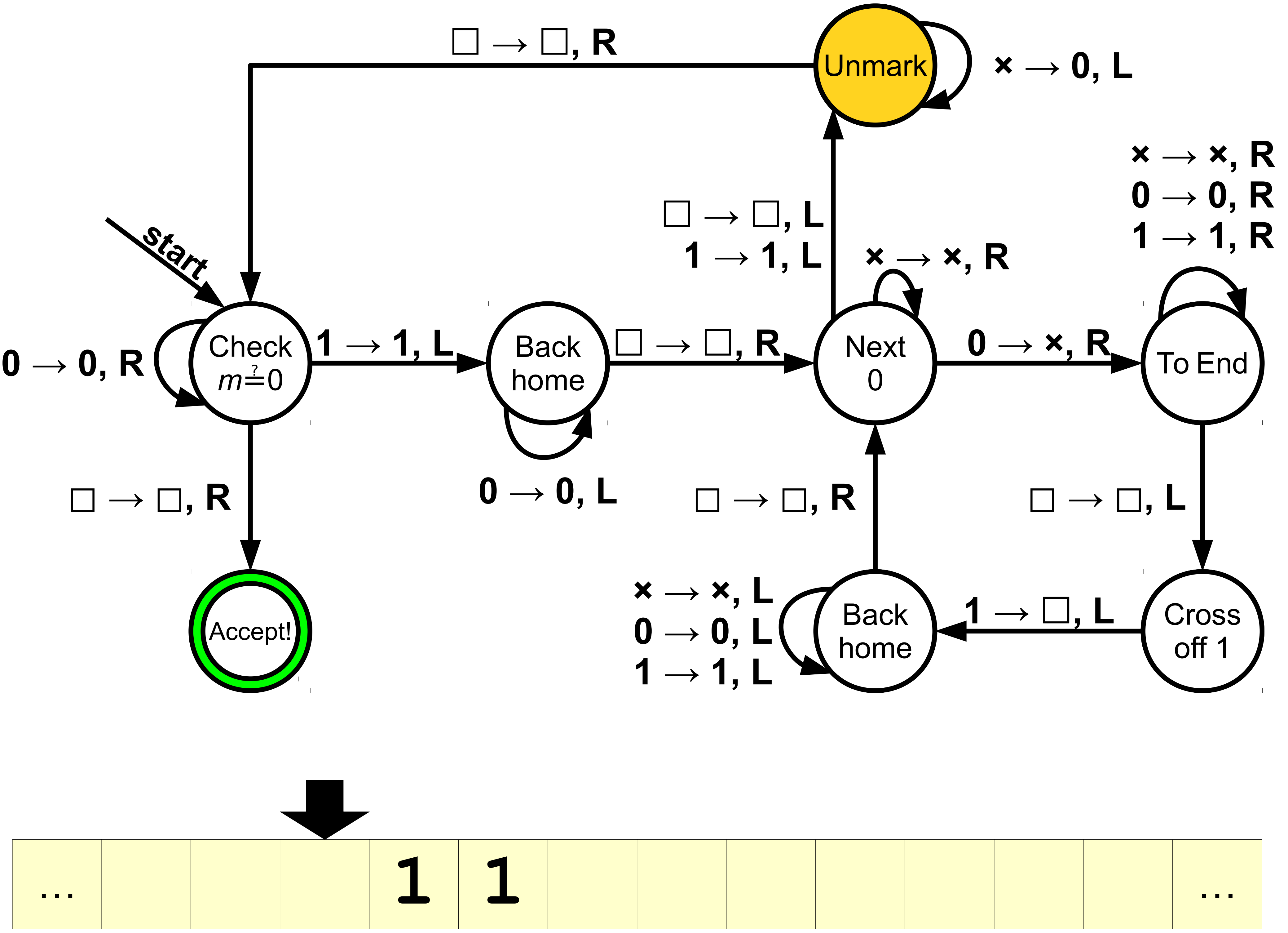

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
1
1
…

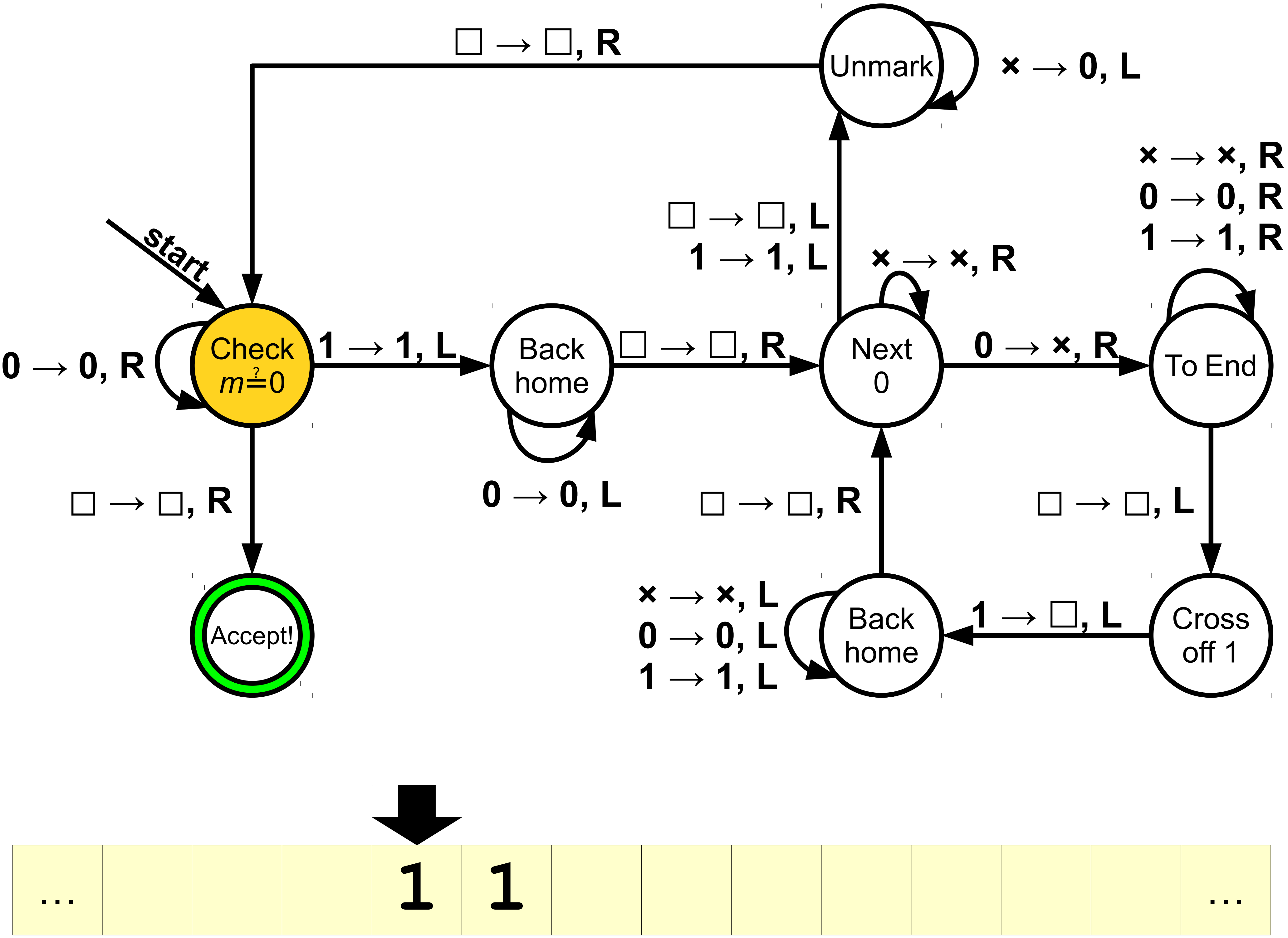

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
m≟0
1 → 1, L
Back home
□ → □, R
Next 0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back home
1 → □, L
Cross off 1
…
1
1
…

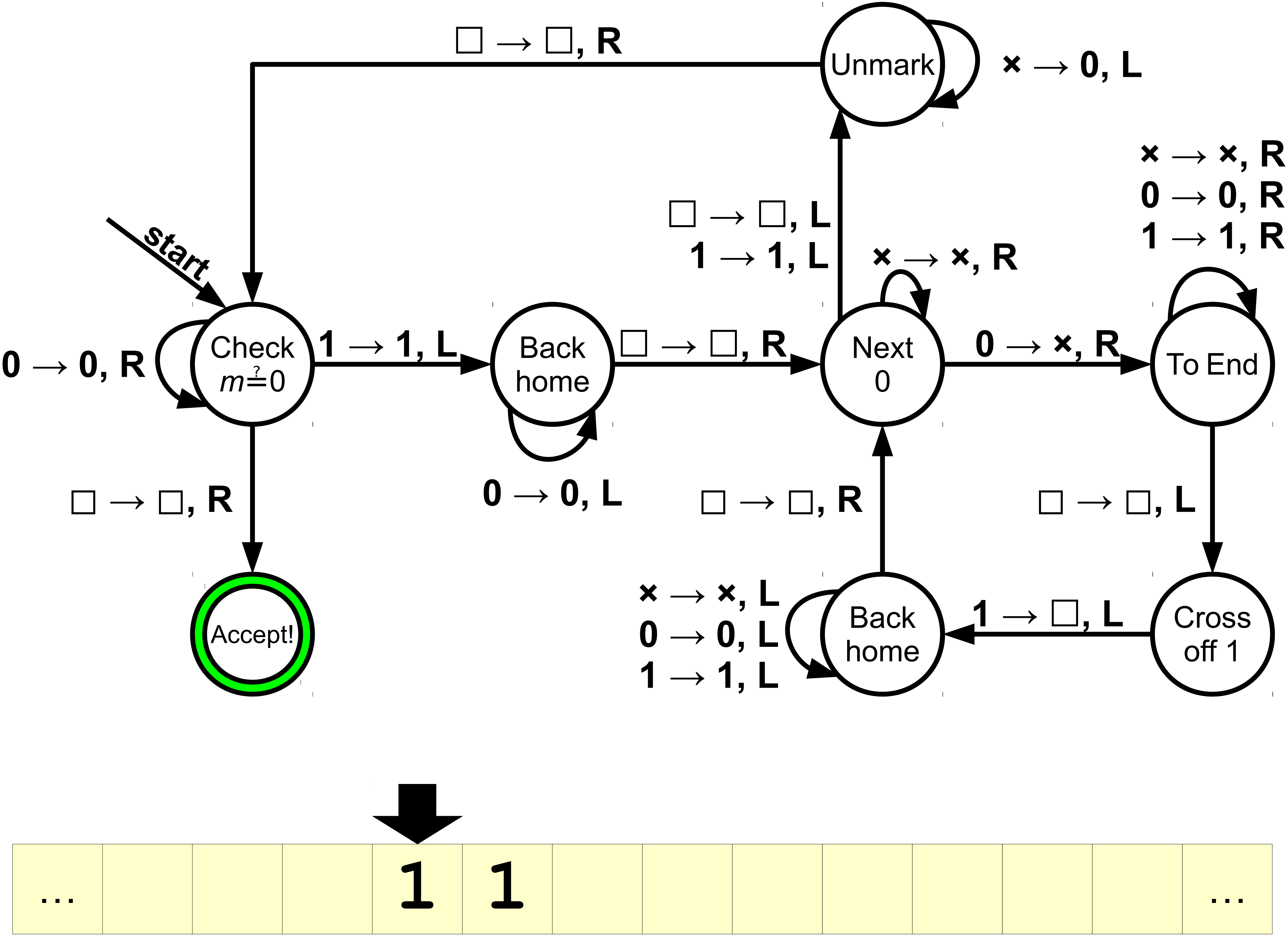

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
m ≟ 0
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1

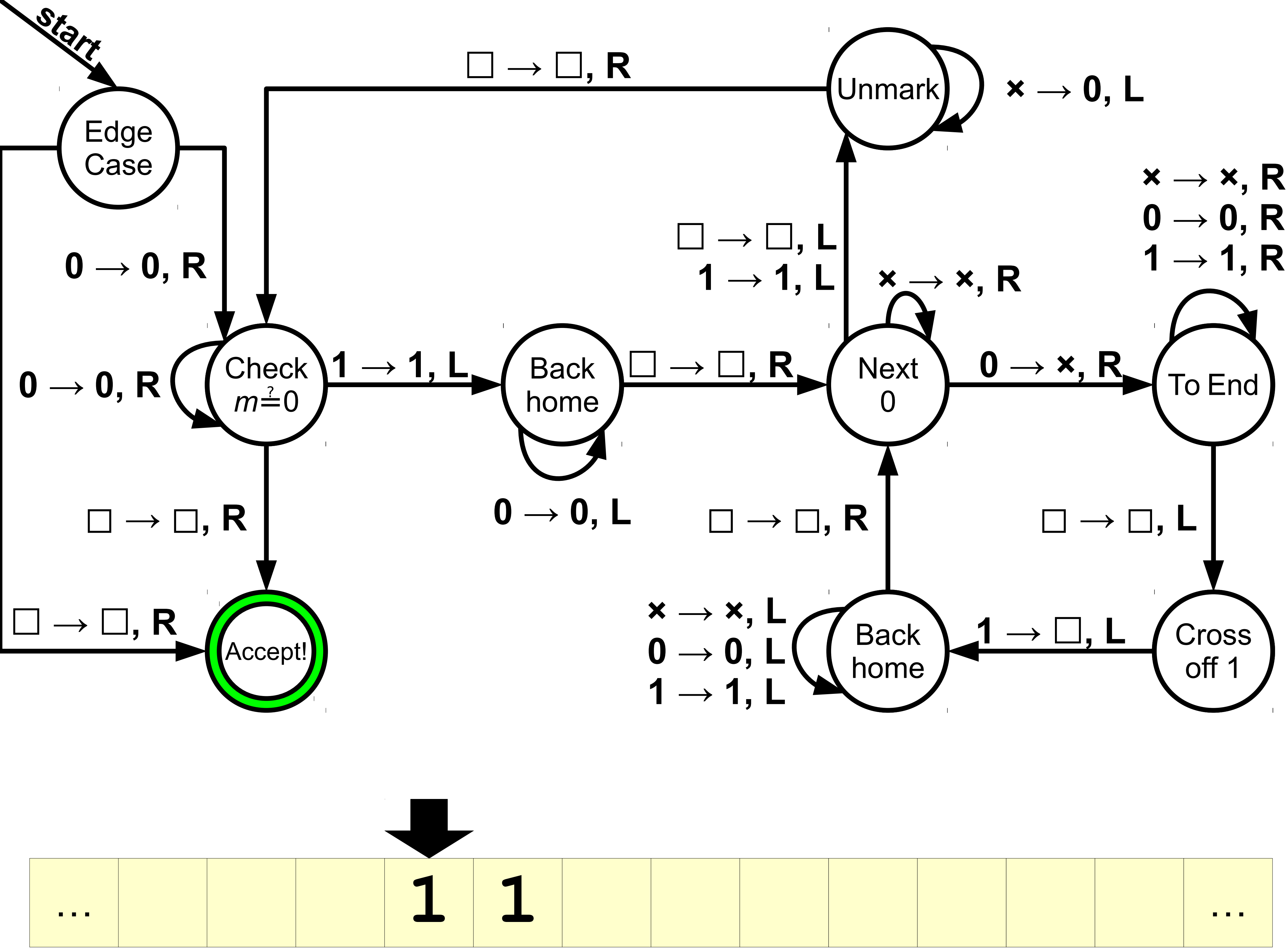
…				1	1								…

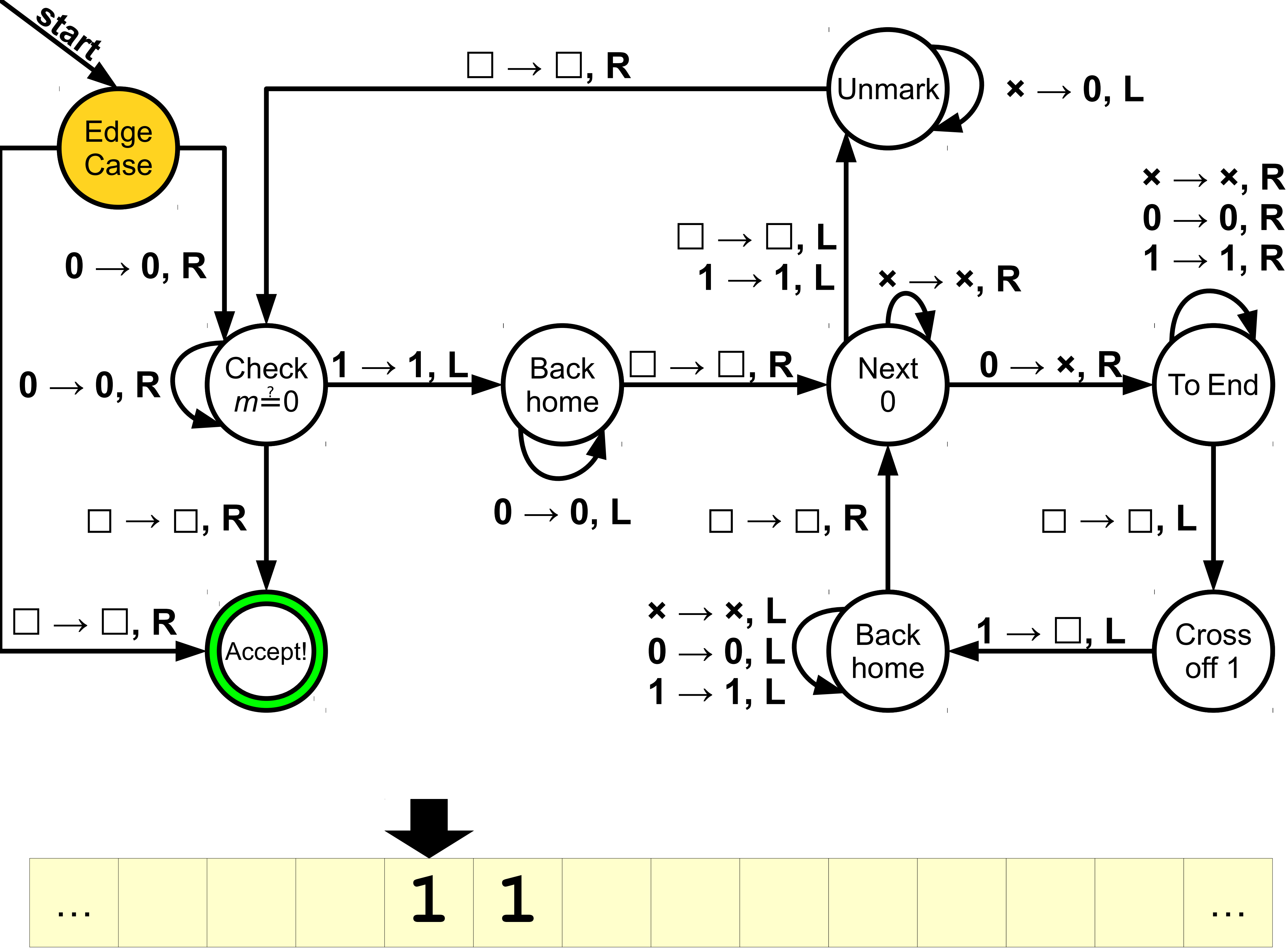

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
1
1
…

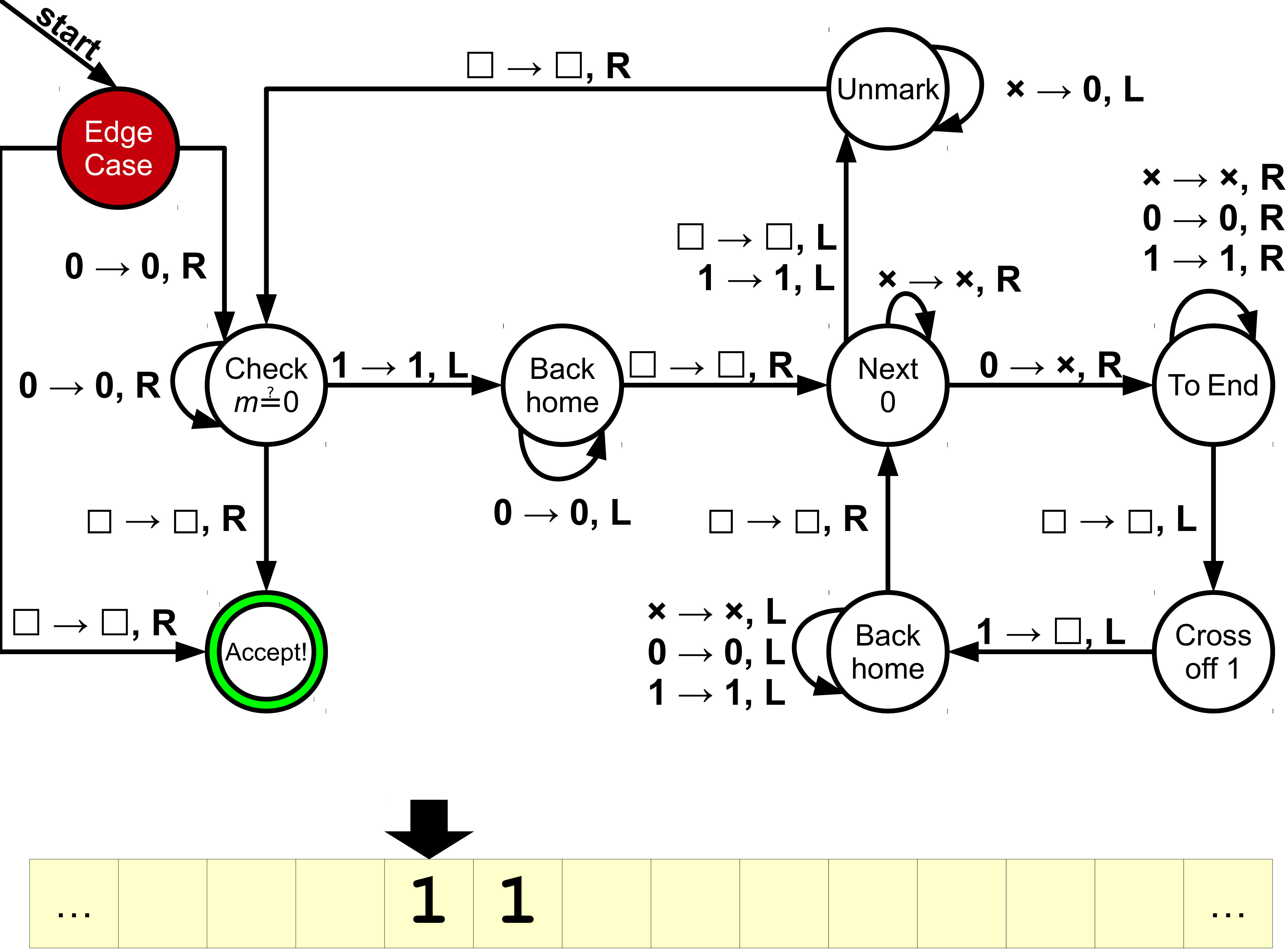

□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \overset{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
…
1
1
…


□ → □, R
Unmark
× → 0, L
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
1 → 1, L
× → ×, R
start
0 → 0, R
Check
$m \stackrel{?}{=} 0$
1 → 1, L
Back
home
□ → □, R
Next
0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
× → ×, L
0 → 0, L
1 → 1, L
Back
home
1 → □, L
Cross
off 1
Accept!
…
1
1
…


start
Check $m \stackrel{?}{=} 0$
0 → 0, R
1 → 1, L
□ → □, R
Accept!
Back home
0 → 0, L
□ → □, R
Next 0
× → ×, R
□ → □, L
1 → 1, L
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
1
1
…


start
Edge Case
0 → 0, R
□ → □, R
Check m ≟ 0
0 → 0, R
□ → □, R
Accept!
1 → 1, L
Back home
0 → 0, L
□ → □, R
Next 0
□ → □, L
1 → 1, L
× → ×, R
Unmark
× → 0, L
□ → □, R
0 → ×, R
To End
× → ×, R
0 → 0, R
1 → 1, R
□ → □, L
Cross off 1
1 → □, L
Back home
× → ×, L
0 → 0, L
1 → 1, L
□ → □, R
…
1
1
…


start
Edge Case
□ → □, R
Unmark
× → 0, L
0 → 0, R
□ → □, L
1 → 1, L
× → ×, R
× → ×, R
0 → 0, R
1 → 1, R
0 → 0, R
Check $m \overset{?}{=} 0$
1 → 1, L
Back home
□ → □, R
Next 0
0 → ×, R
To End
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
□ → □, R
Accept!
× → ×, L
0 → 0, L
1 → 1, L
Back home
1 → □, L
Cross off 1
…
1
1
…


start
Edge Case
Check $m \overset{?}{=} 0$
Back home
Next 0
To End
Unmark
Accept!
Back home
Cross off 1
□ → □, R
× → 0, L
0 → 0, R
0 → 0, R
1 → 1, L
□ → □, R
0 → ×, R
□ → □, L
1 → 1, L
× → ×, R
× → ×, R
0 → 0, R
1 → 1, R
0 → 0, L
□ → □, R
□ → □, R
□ → □, L
□ → □, R
× → ×, L
0 → 0, L
1 → 1, L
1 → □, L
…
1
1
…

Concepts from Today

- Turing machines are a generalization of finite automata equipped with an infinite tape.
- It's often helpful to think recursively when designing Turing machines.
- It's often helpful to introduce new symbols into the tape alphabet.
- Watch for edge cases that might lead to infinite loops – though we'll say more about that later on.

Next Time

- **TM Subroutines**
  - Combining multiple TMs together!
- **The Church-Turing Thesis**
  - Just how powerful *are* Turing machines?
- **Objects and Encodings**
  - Computing on graphs, images, etc.