L'automate autoréplicateur de von Neumann

Jean-Luc Beuchat

Laboratoire de Systèmes Logiques

Ecole Polytechnique Fédérale de Lausanne

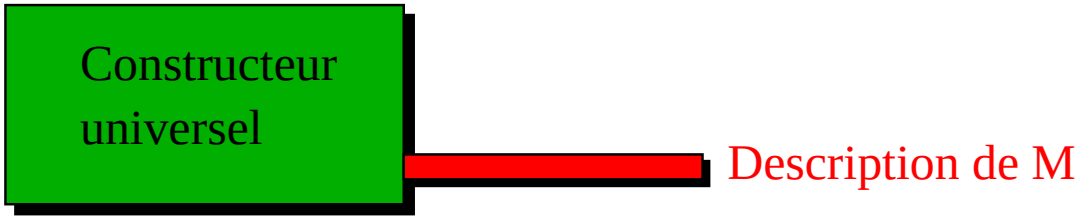
CH – 1015 Lausanne

e-mail : Jean-Luc.Beuchat@epfl.ch

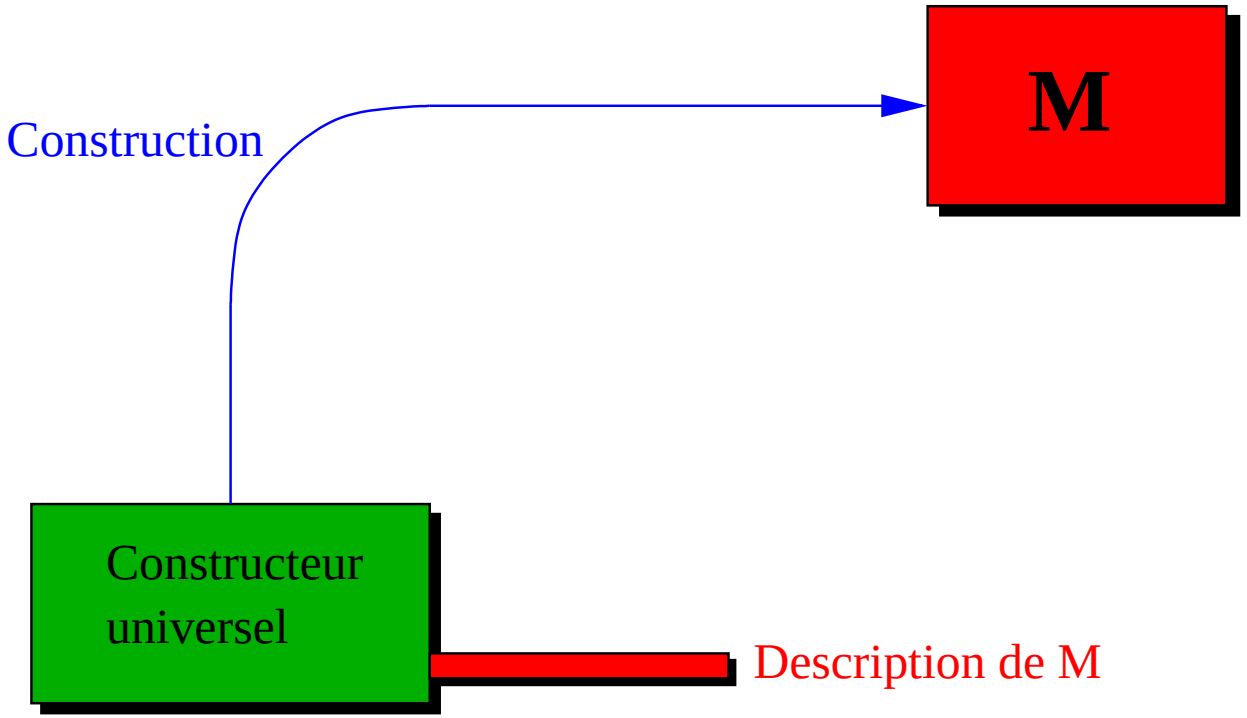
Plan du cours

- Propriétés
- Autoréplication
- Description de l'automate
- Applications

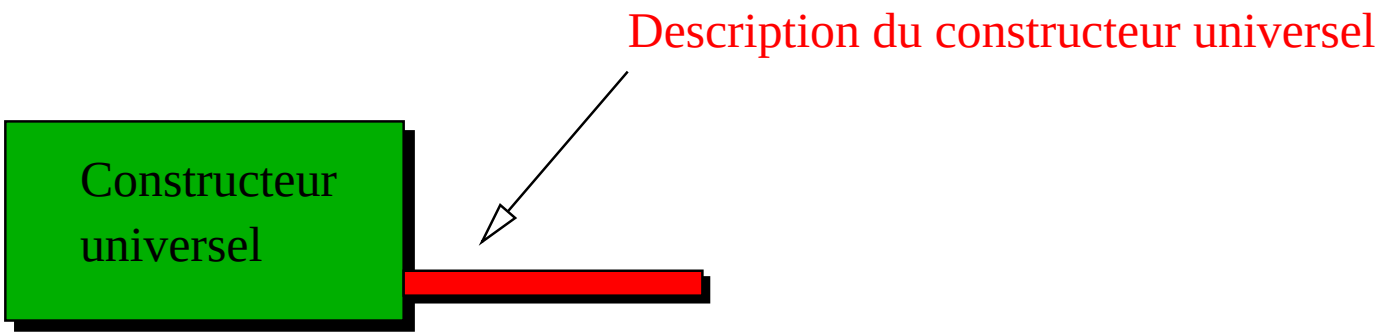
- Machine à construire universelle



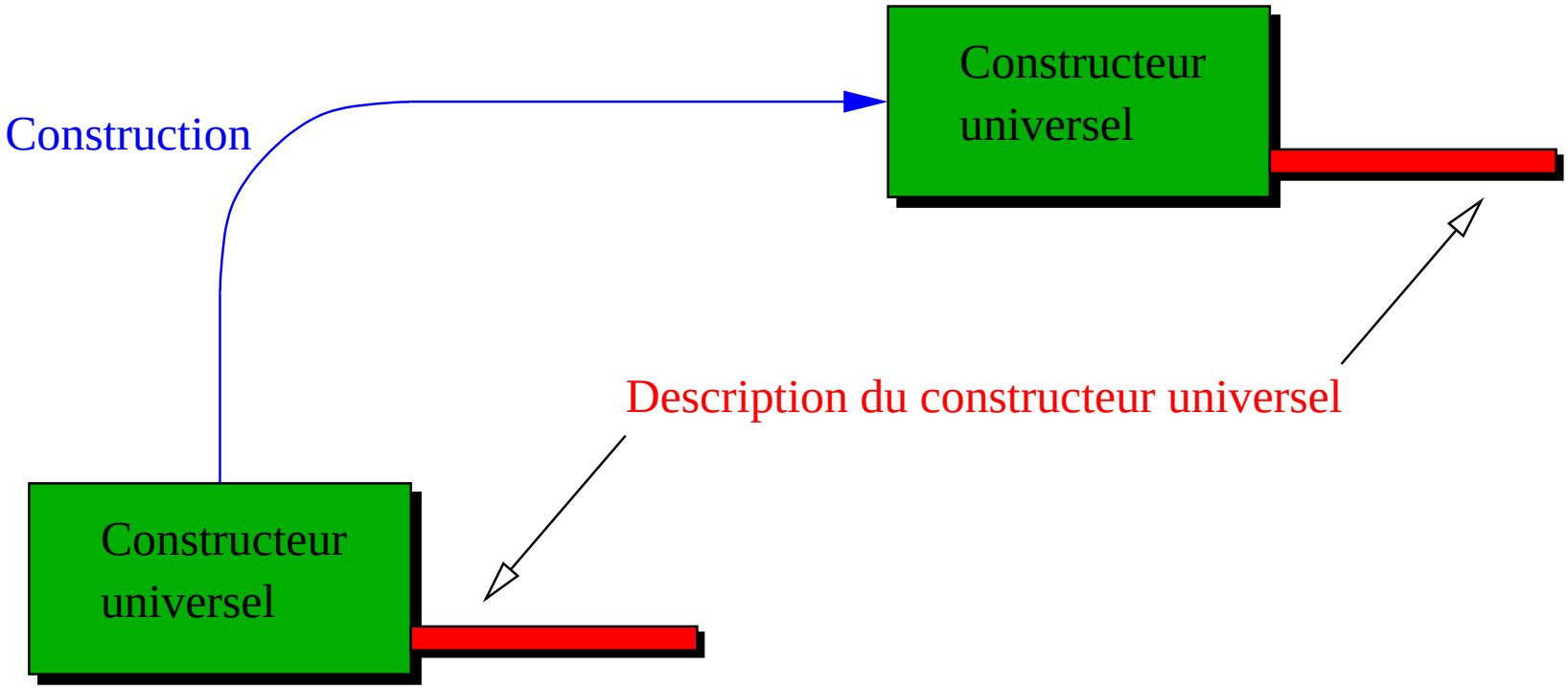
- Machine à construire universelle



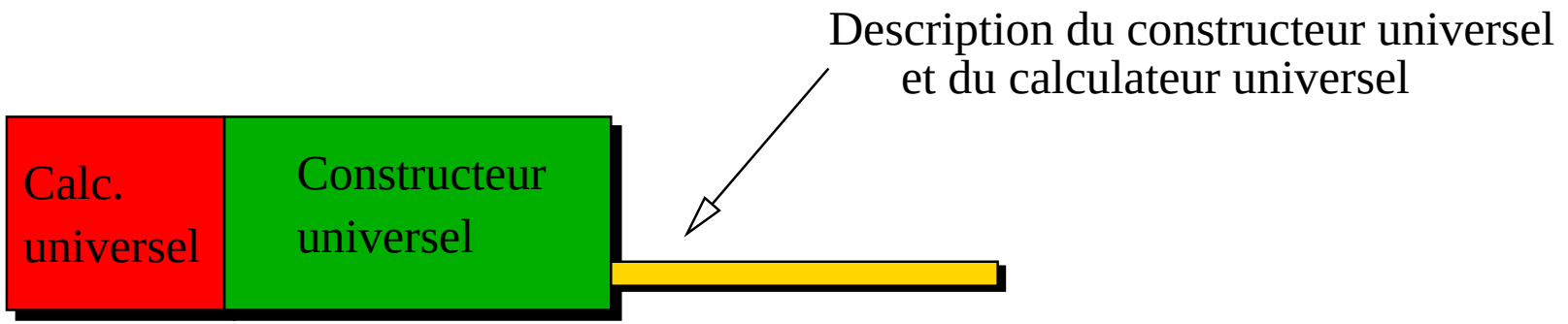
- Autoréplication



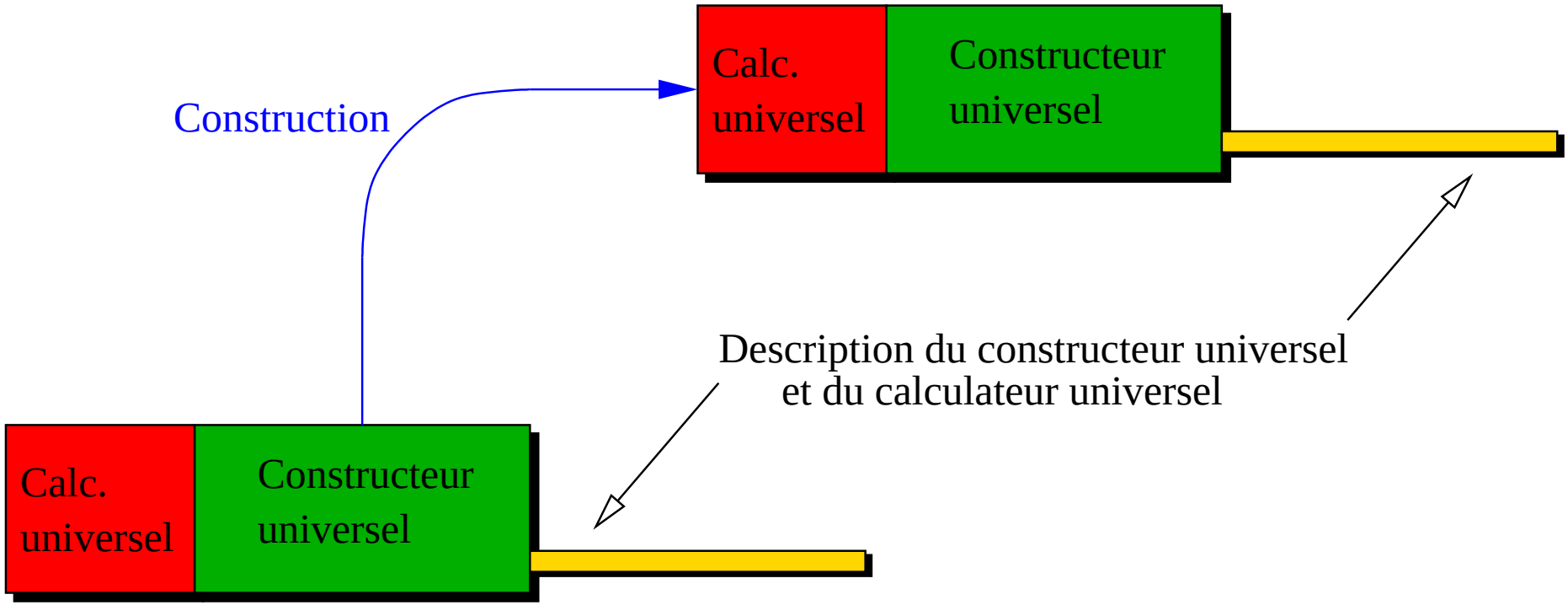
Autoréplication

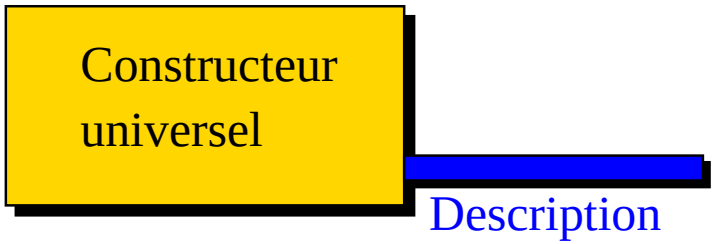


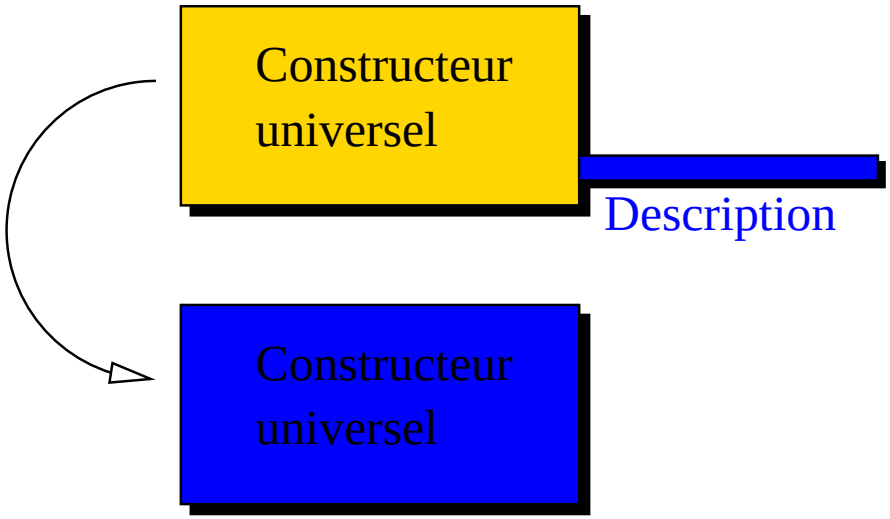
- Autoréplication d'un calculateur universel

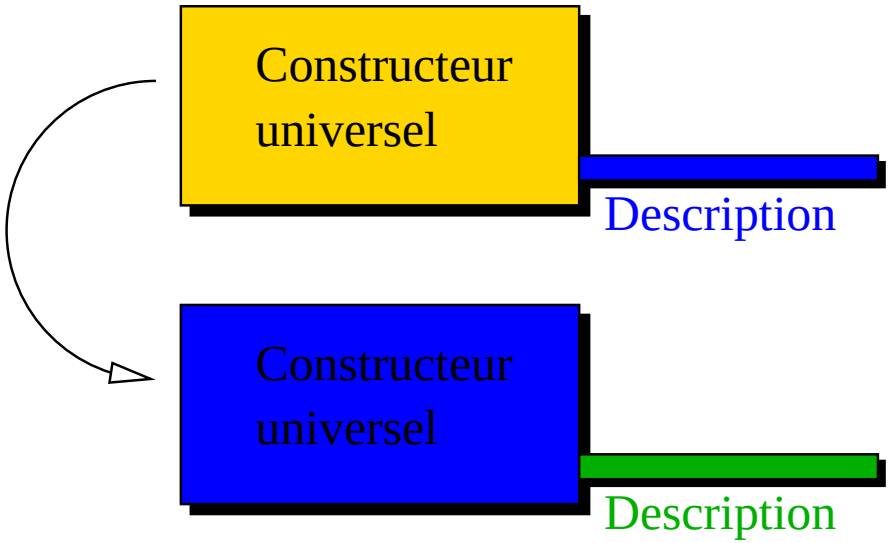


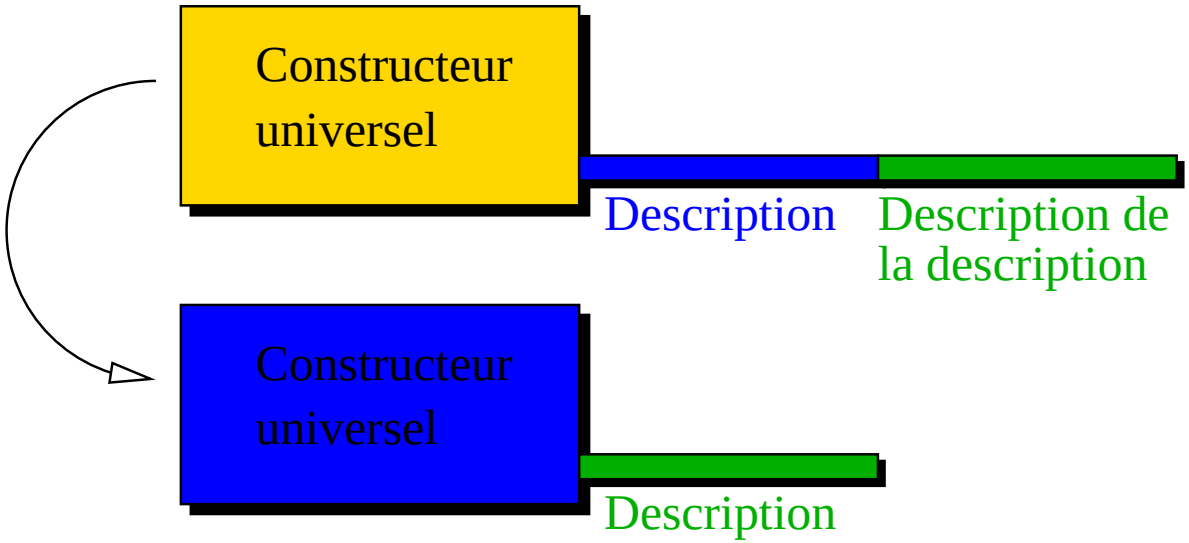
Autoréplication d'un calculateur universel

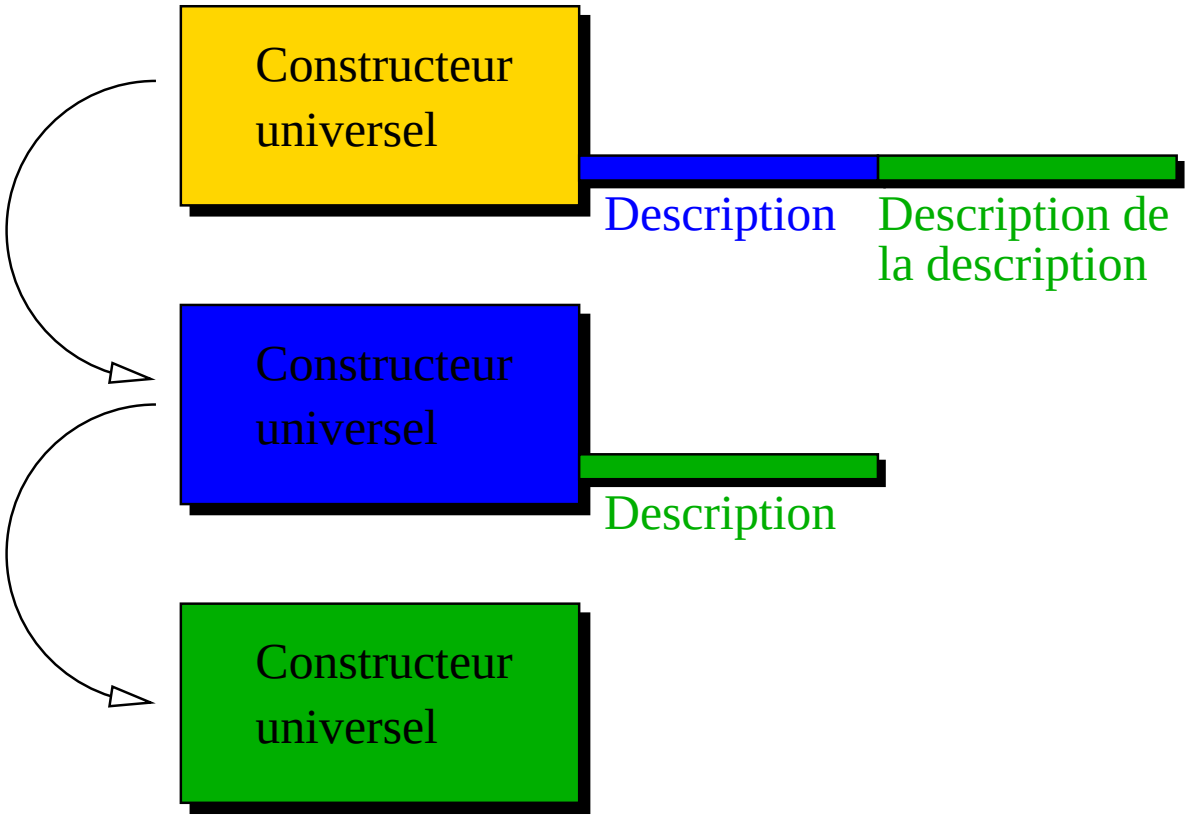


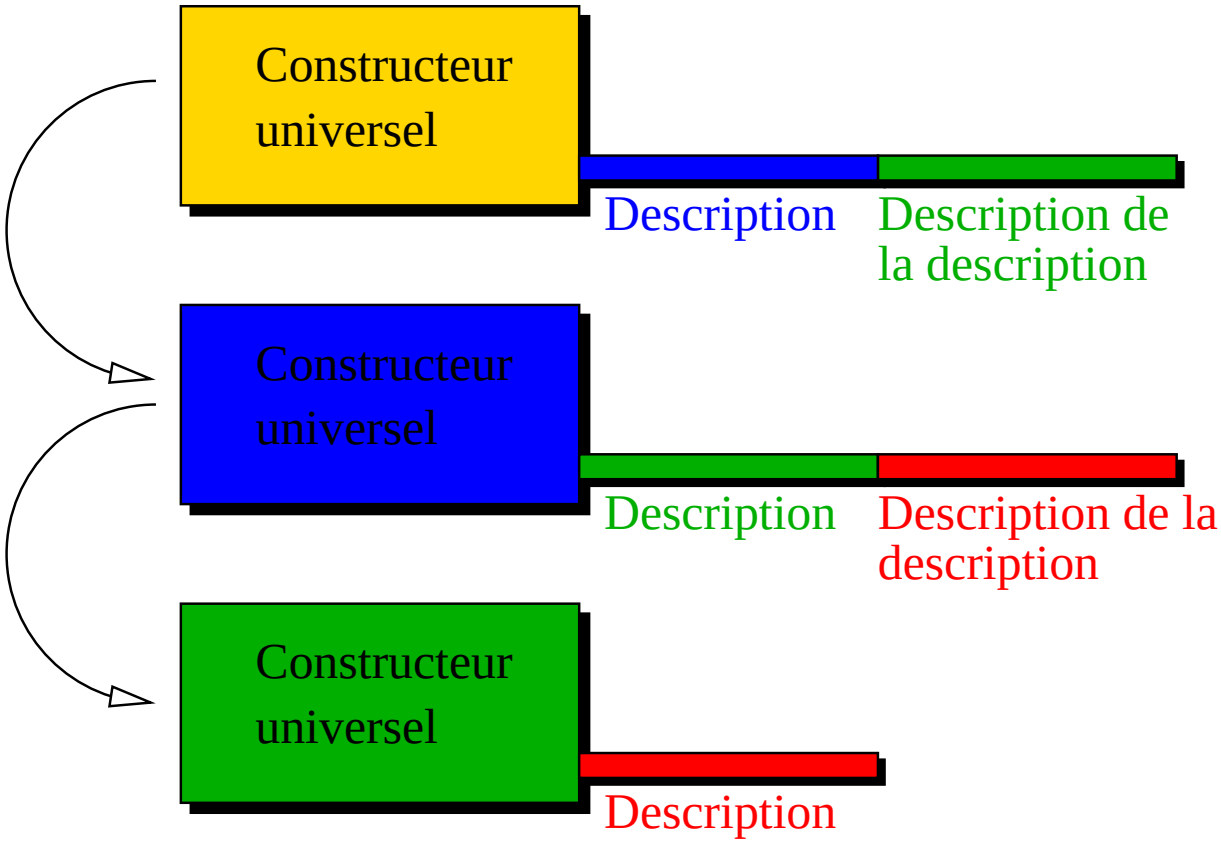

Constructeur
universel
Description

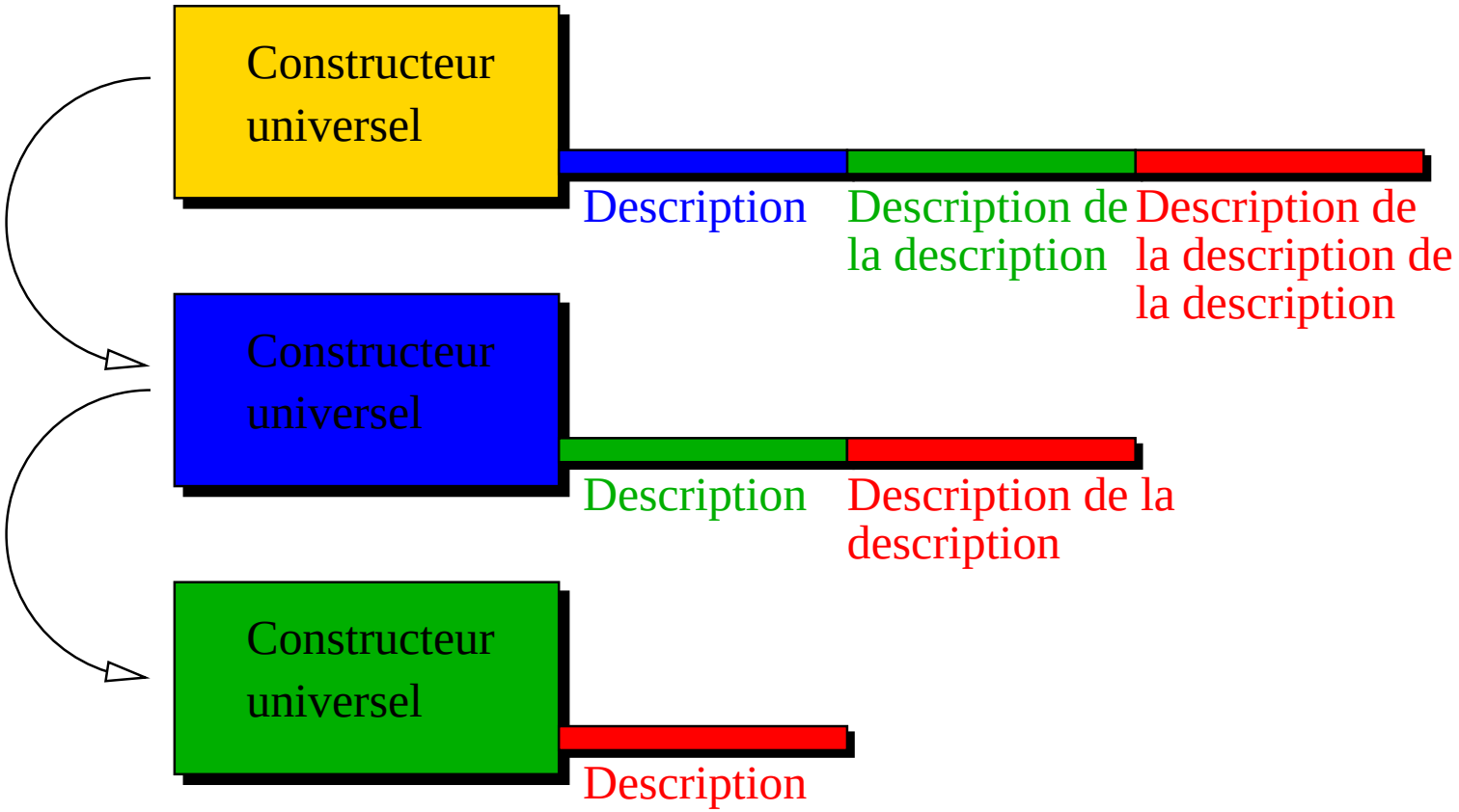

Constructeur
universel
Description
Constructeur
universel

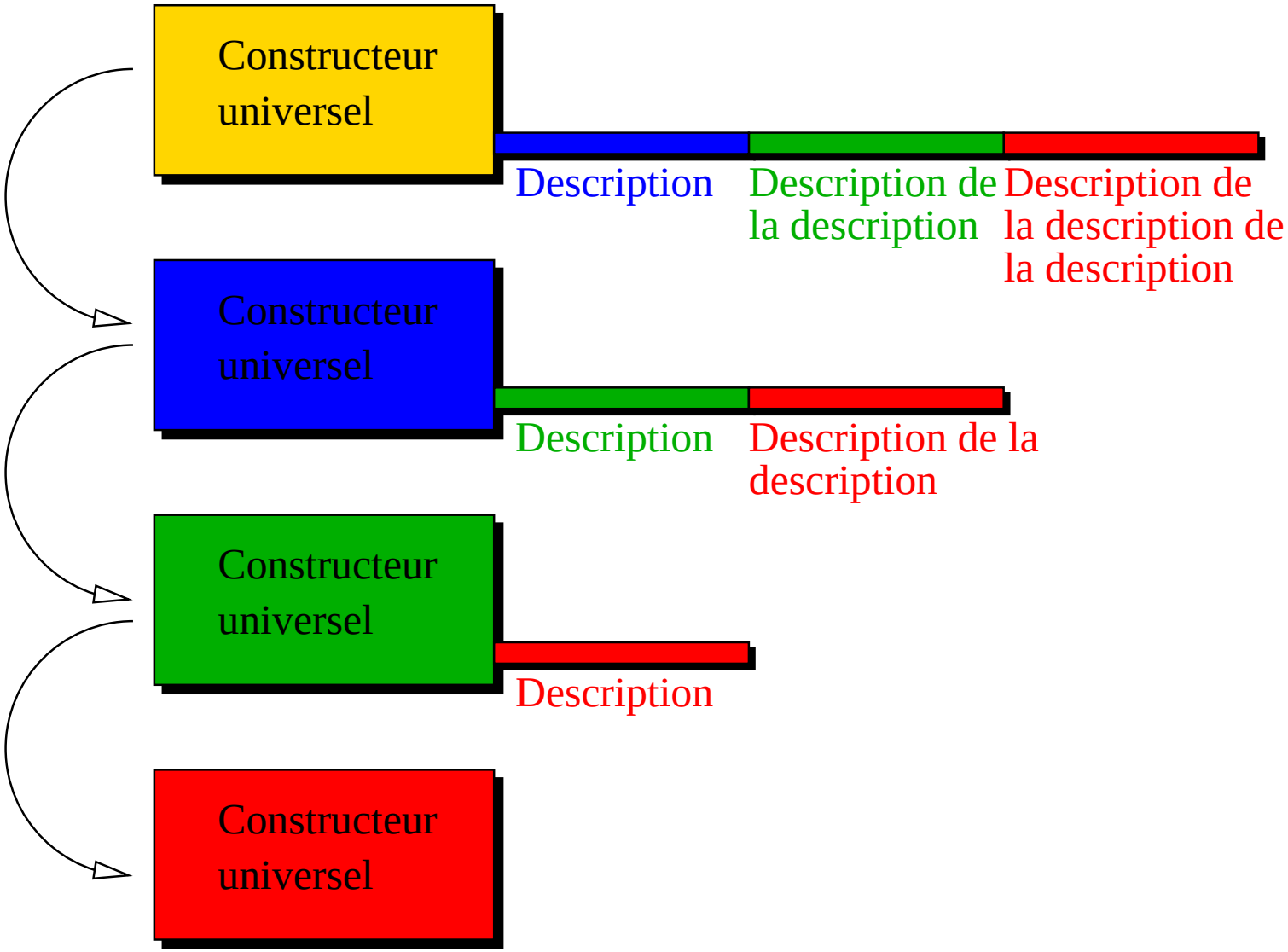

Constructeur
universel
Description
Constructeur
universel
Description

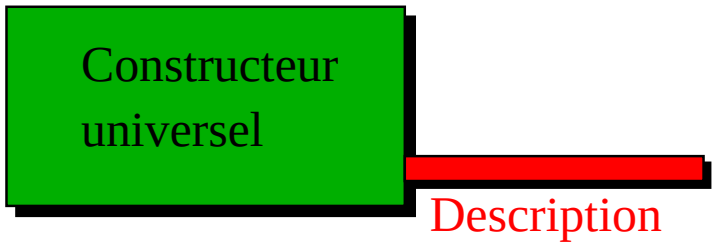

Constructeur
universel
Description
Description de
la description
Constructeur
universel
Description

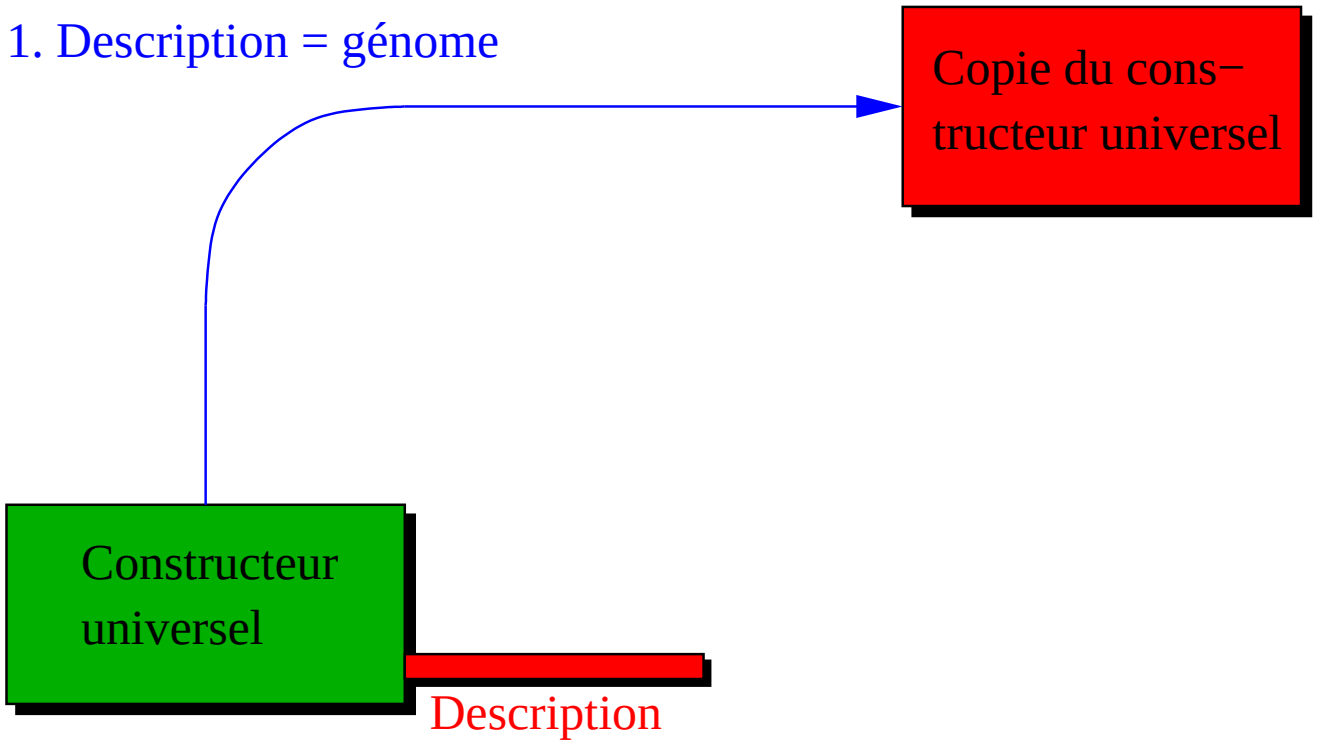

Constructeur universel
Description
Description de la description
Constructeur universel
Description
Constructeur universel

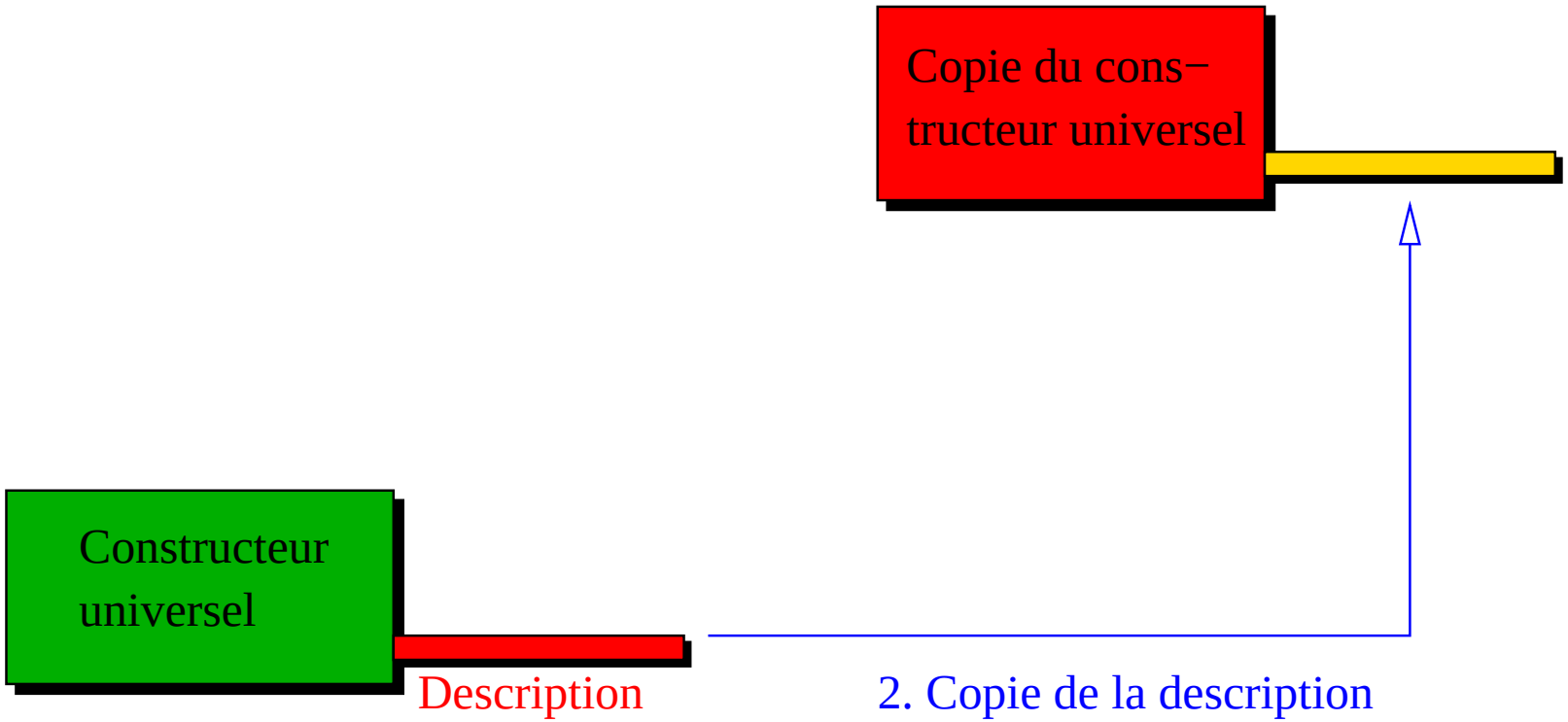

Constructeur universel
Description
Description de la description
Constructeur universel
Description
Description de la description
Constructeur universel
Description


Constructeur universel
Description
Description de la description
Description de la description de la description
Constructeur universel
Description
Description de la description
Constructeur universel
Description

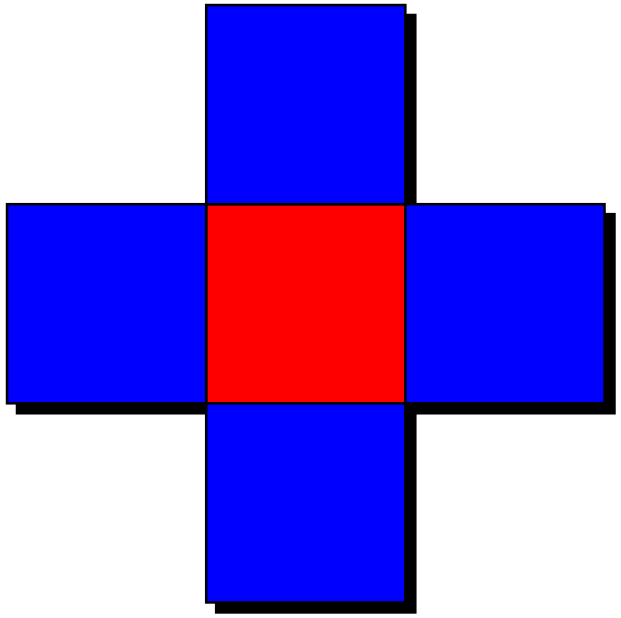

Constructeur universel
Description
Description de la description
Description de la description de la description
Constructeur universel
Description
Description de la description
Constructeur universel
Description
Constructeur universel


Constructeur
universel
Description


1. Description = génome
Copie du cons−
tructeur universel
Constructeur
universel
Description

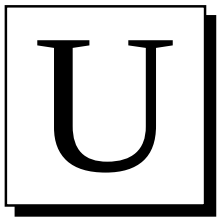

Copie du cons−
tructeur universel
Constructeur
universel
Description
2. Copie de la description

Univers



- Automate cellulaire
  - 29 états
  - voisinage de 5 cellules

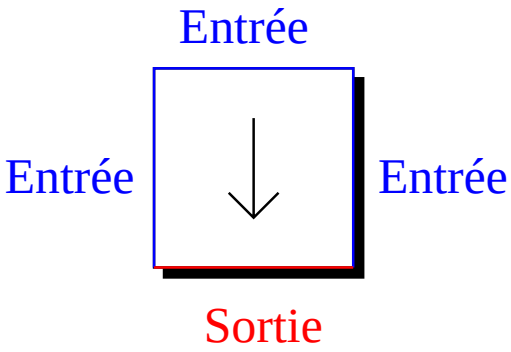
L’état quiescent



- Cellule morte
- Aucune influence sur les cellules voisines

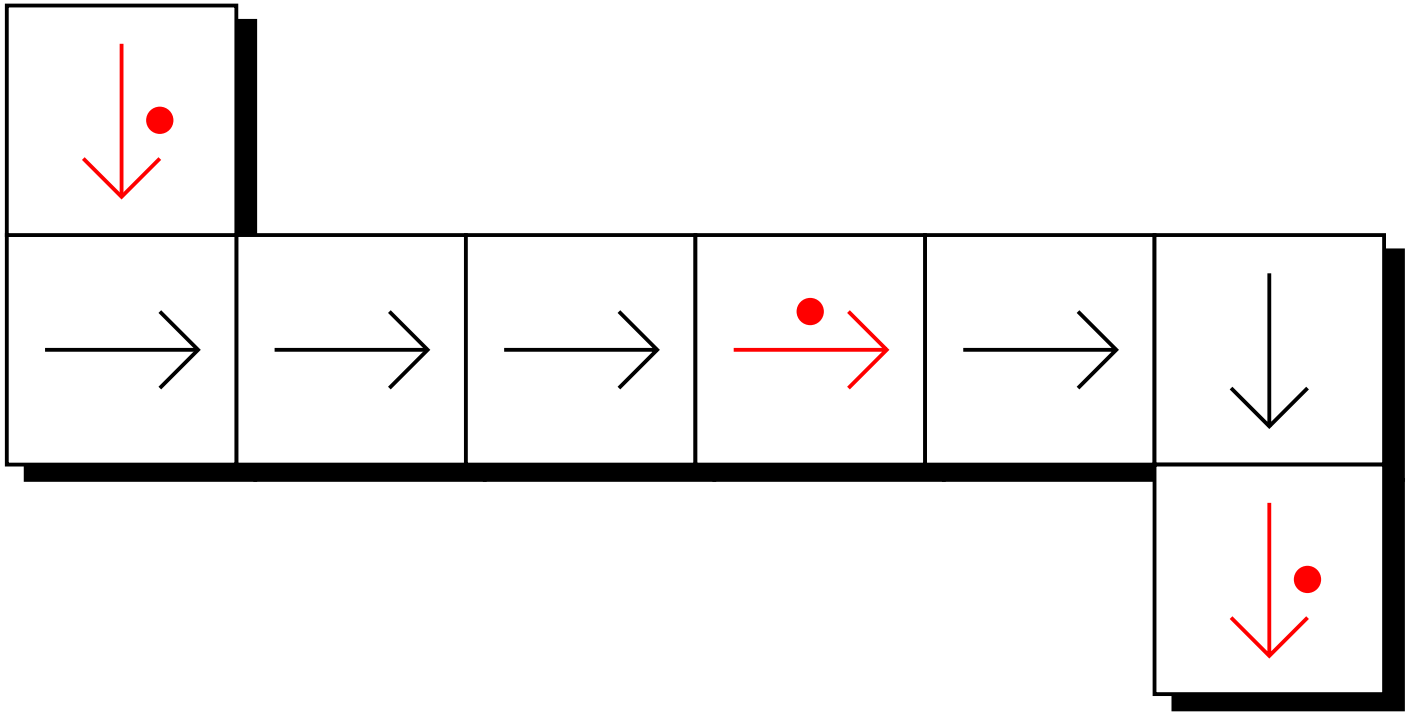
Etats de transmission ordinaires

- Non excités : $\uparrow$ $\downarrow$ $\rightarrow$ $\leftarrow$
- Excités : $\uparrow\!\cdot$ $\downarrow\!\cdot$ $\dot{\rightarrow}$ $\dot{\leftarrow}$



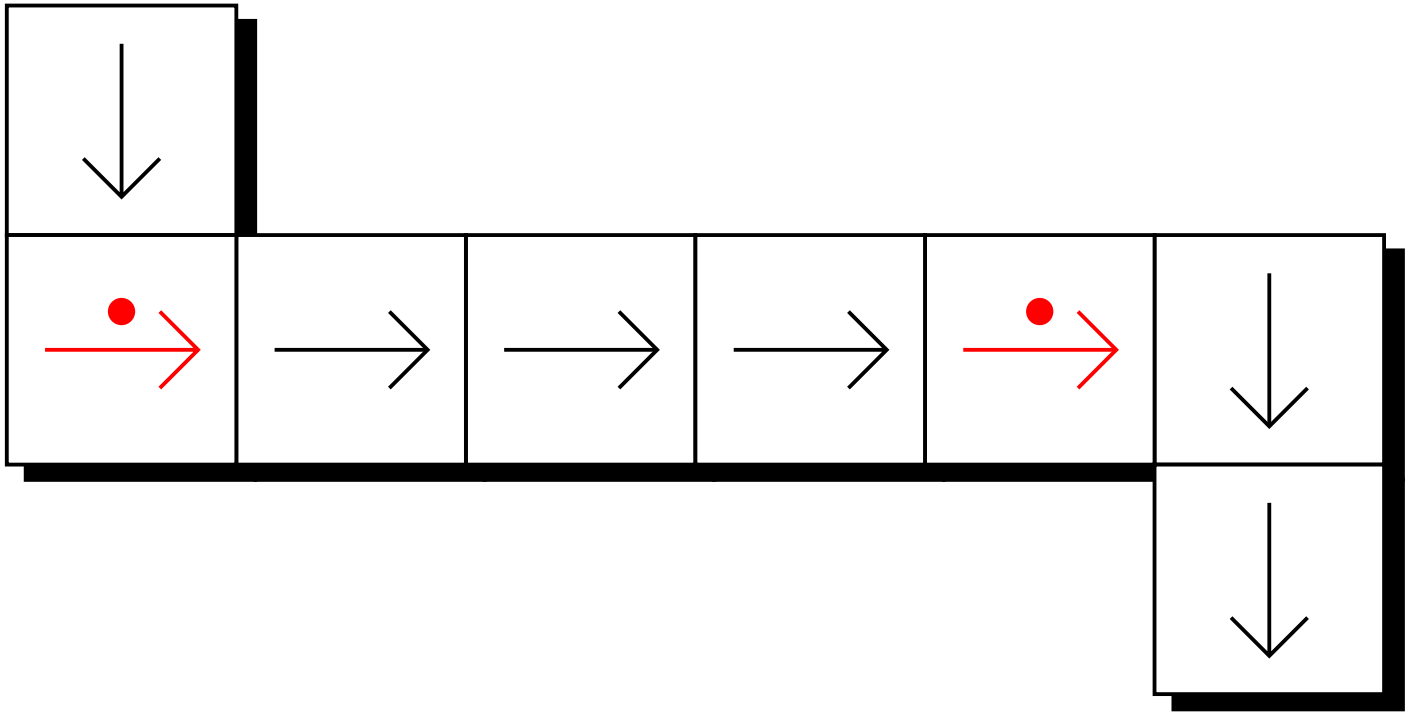
Propriétés (1)

⇒ Transmission d’excitations avec un délai unité

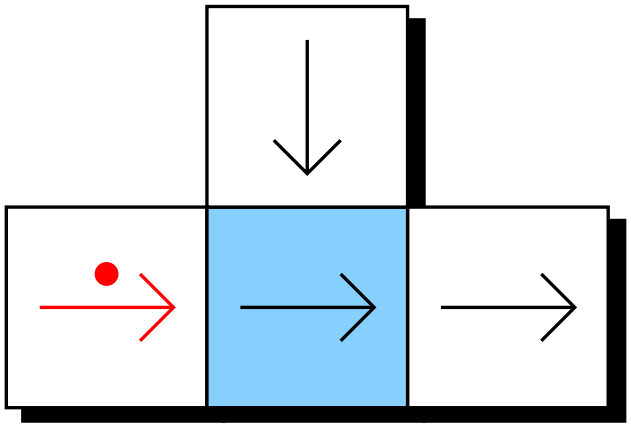


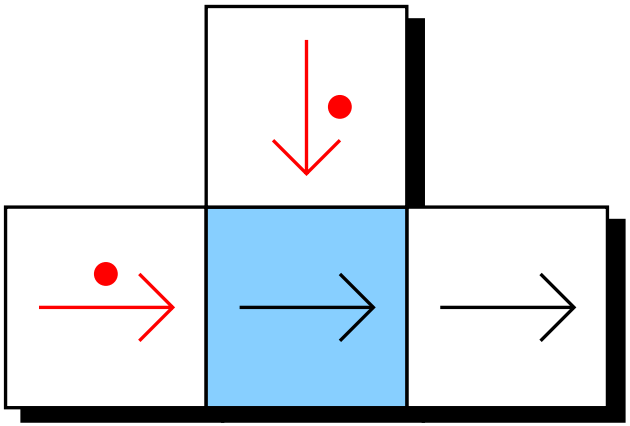
Propriétés (1)

- Transmission d’excitations avec un délai unité

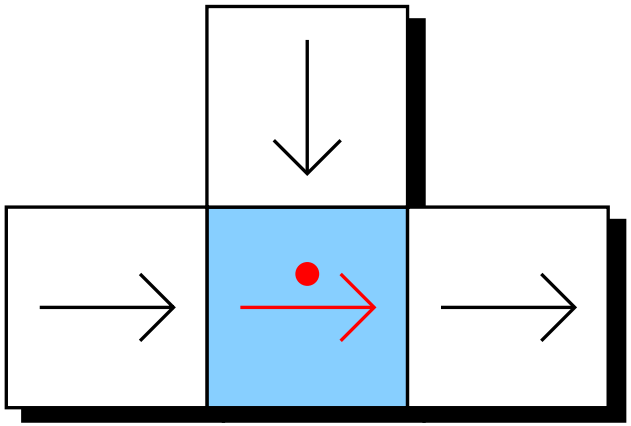


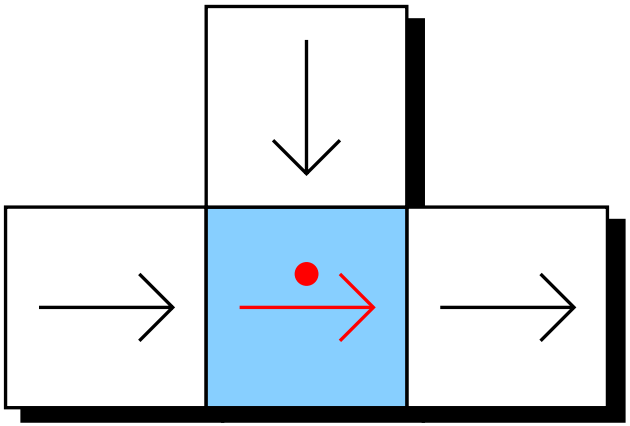
- Propriétés (2)
  - Porte logique OU



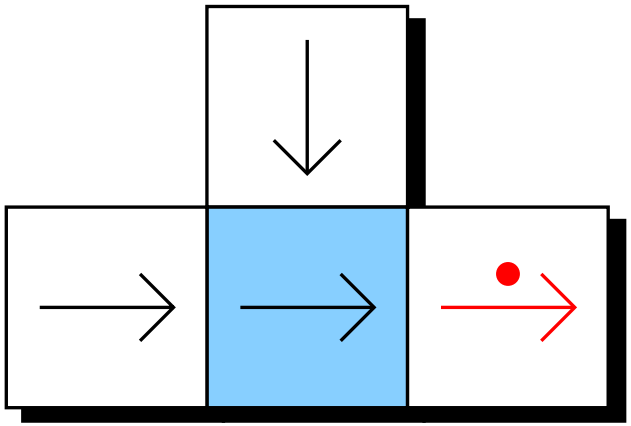


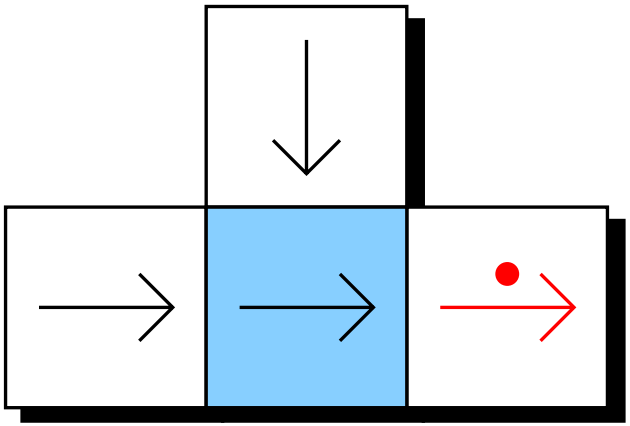
- Propriétés (2)
  - Porte logique OU





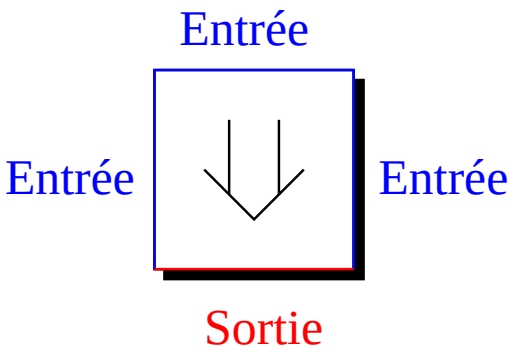
- Propriétés (2)
  - Porte logique OU



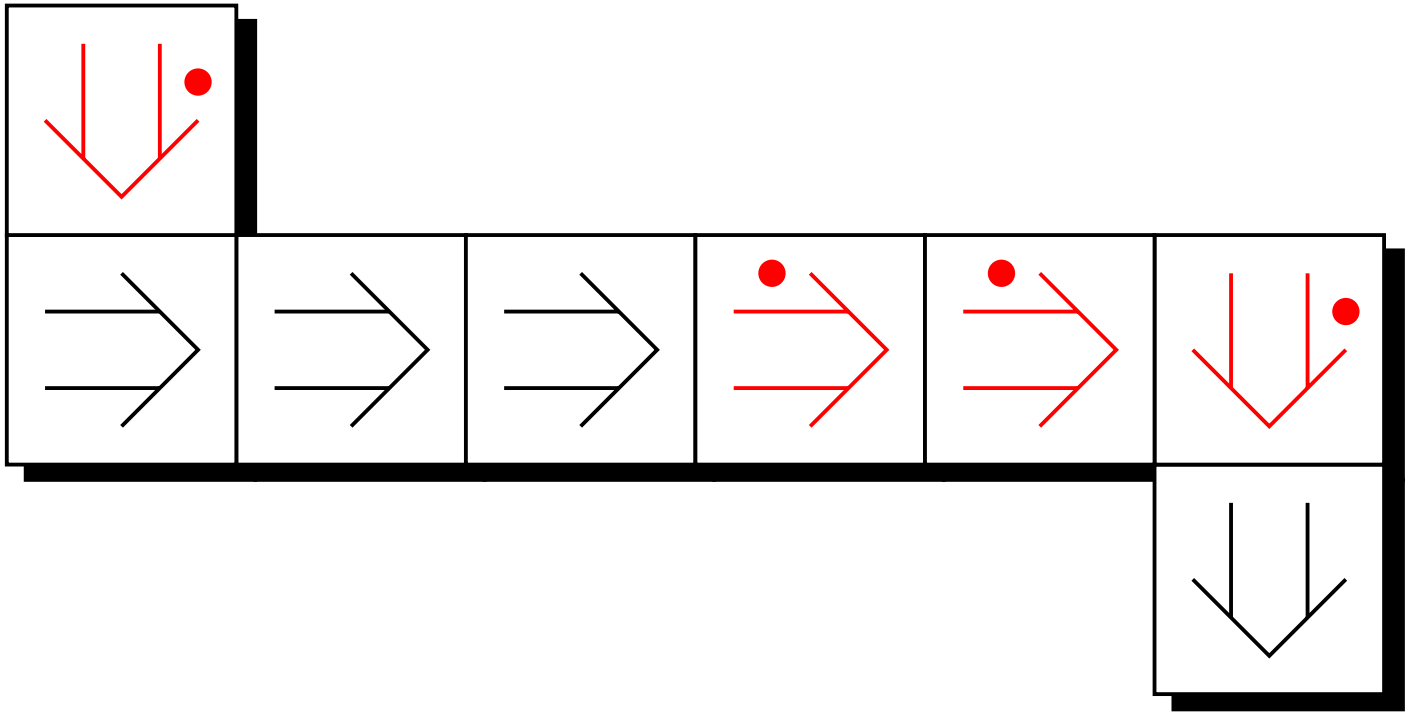


Etats de transmission spéciaux

- Non excités : ⇑ ⇓ ⇒ ⇐
- Excités : ⇑· ⇓· ⇒ ⇐

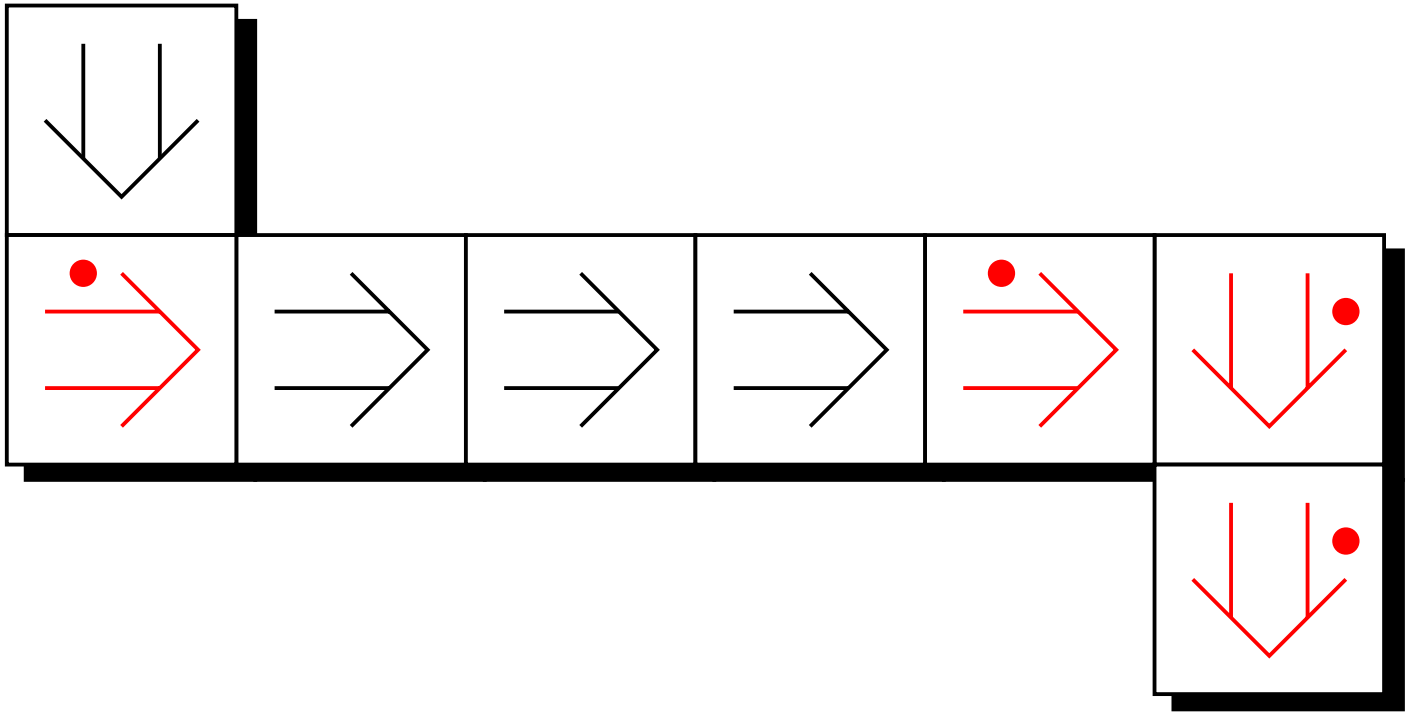


- Propriétés (1)
  - ⇒ Transmission d’excitations avec un délai unité

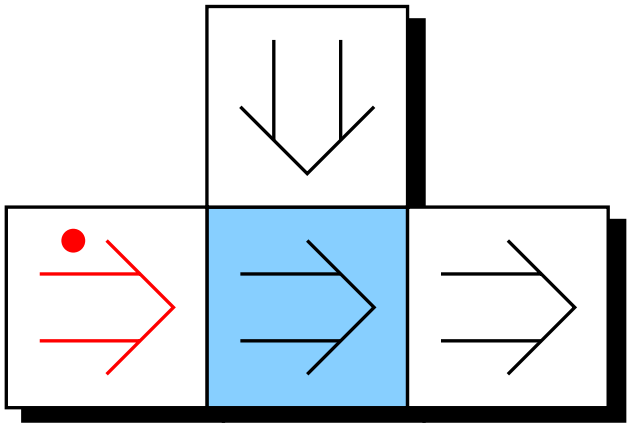


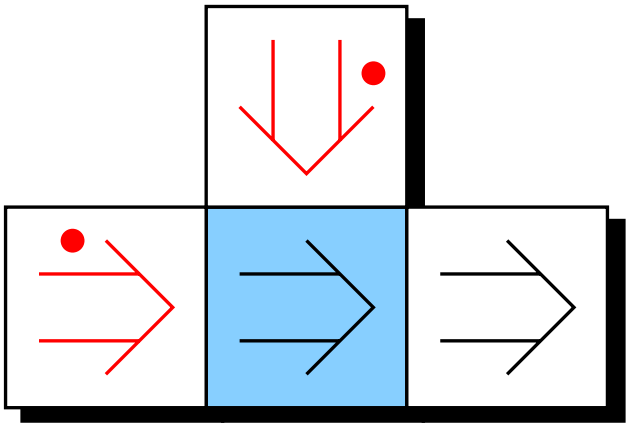
Propriétés (1)

- Transmission d’excitations avec un délai unité

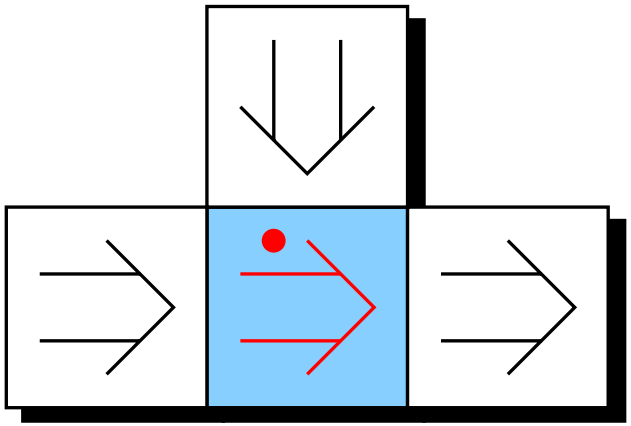


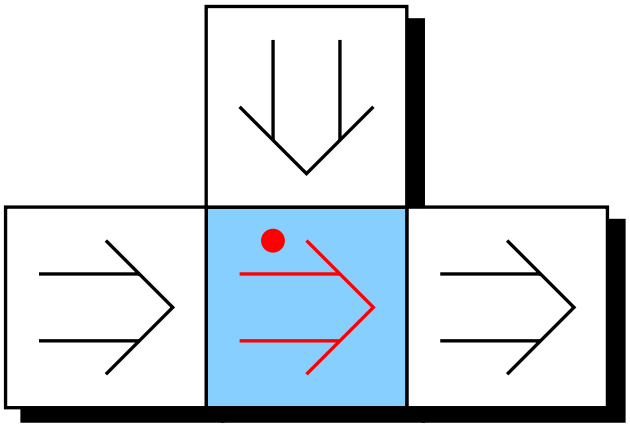
- Propriétés (2)
  - Porte logique OU



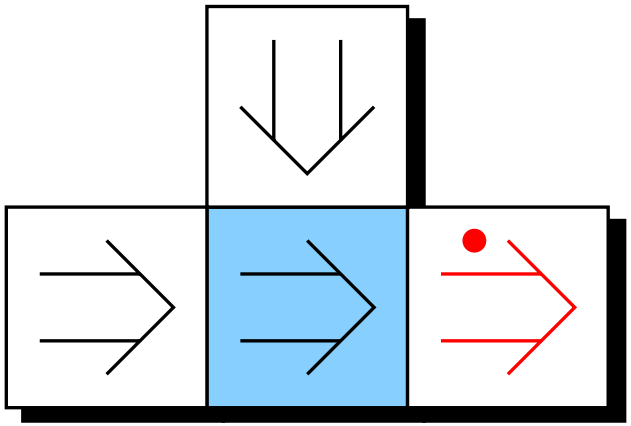


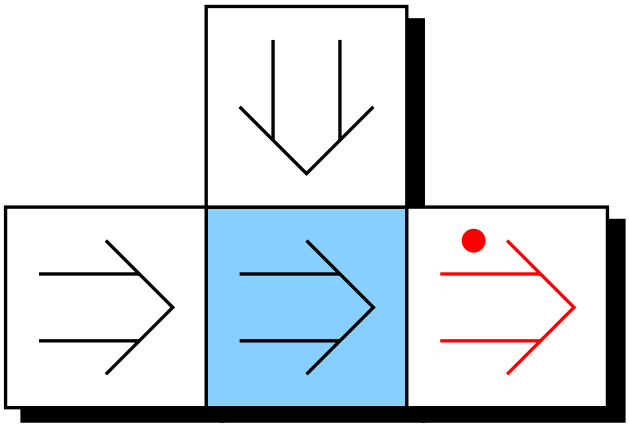
- Propriétés (2)
  - Porte logique OU



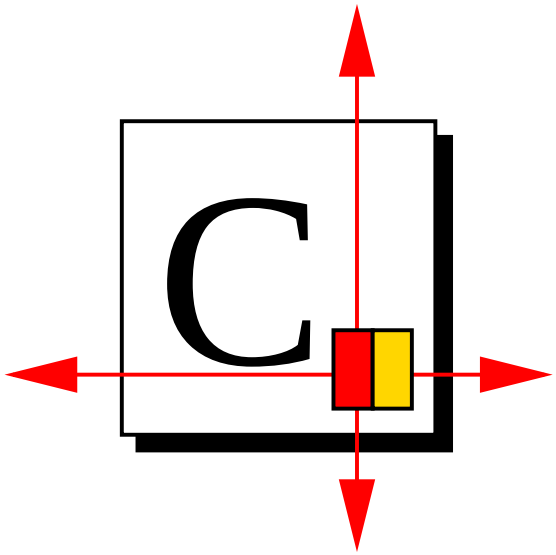


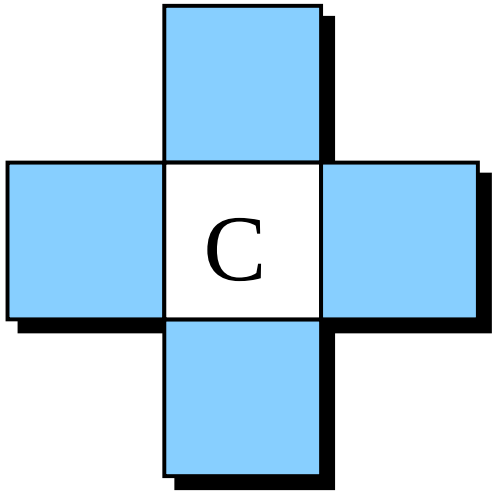
- Propriétés (2)
  - Porte logique OU



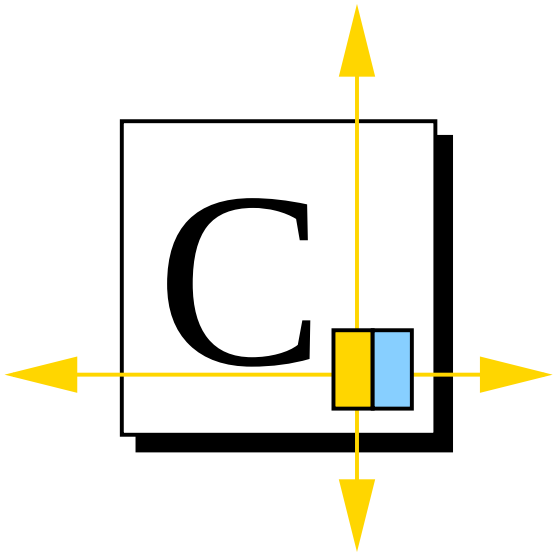


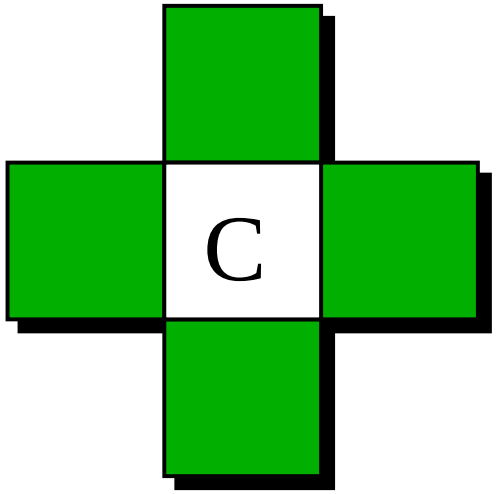
Etats confluents



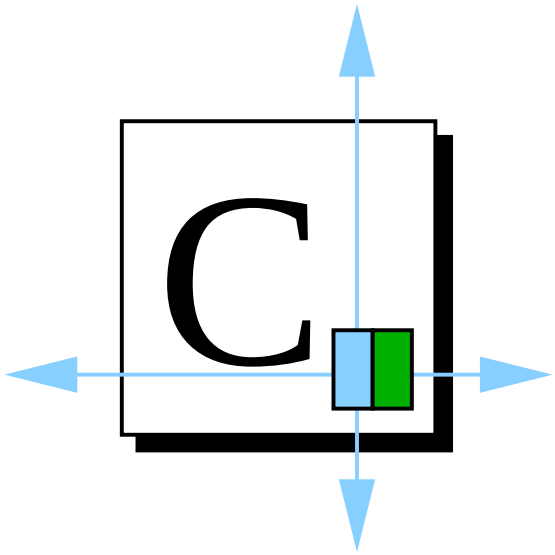


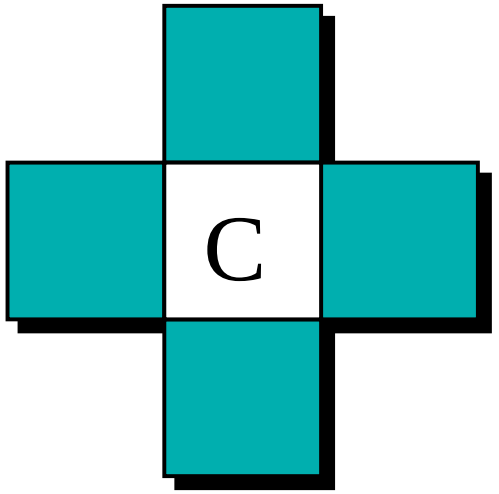
Etats confluents



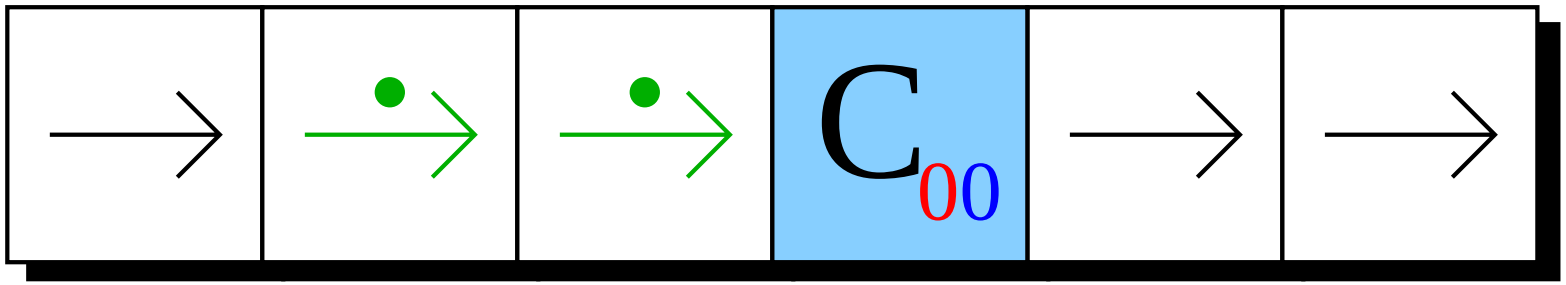


Etats confluents

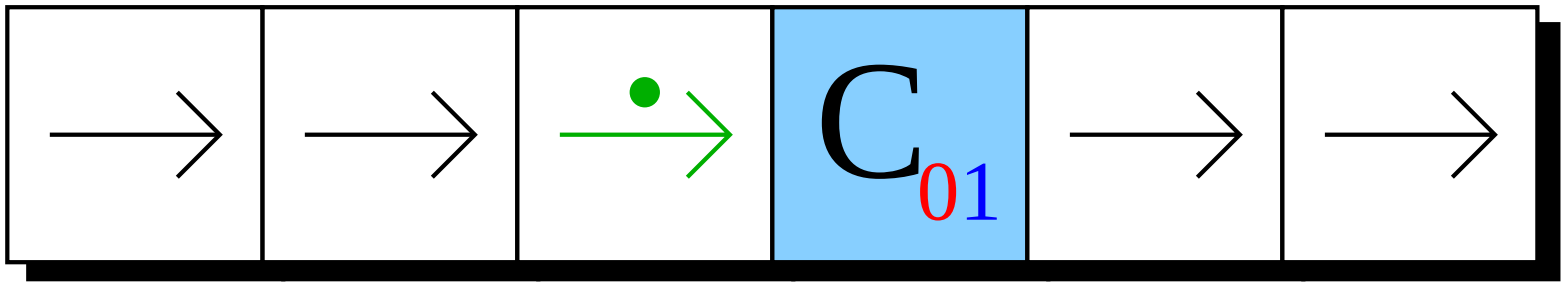




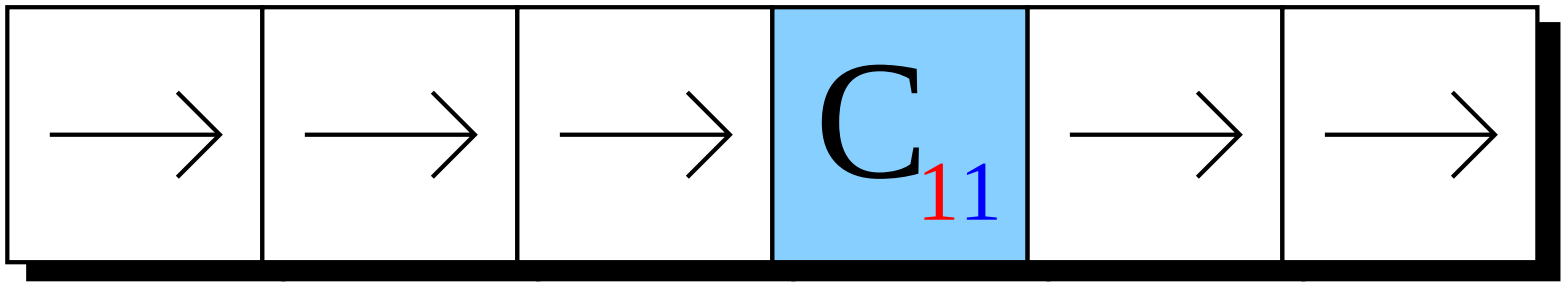
- Propriétés (1)
  - Introduction d’un double délai



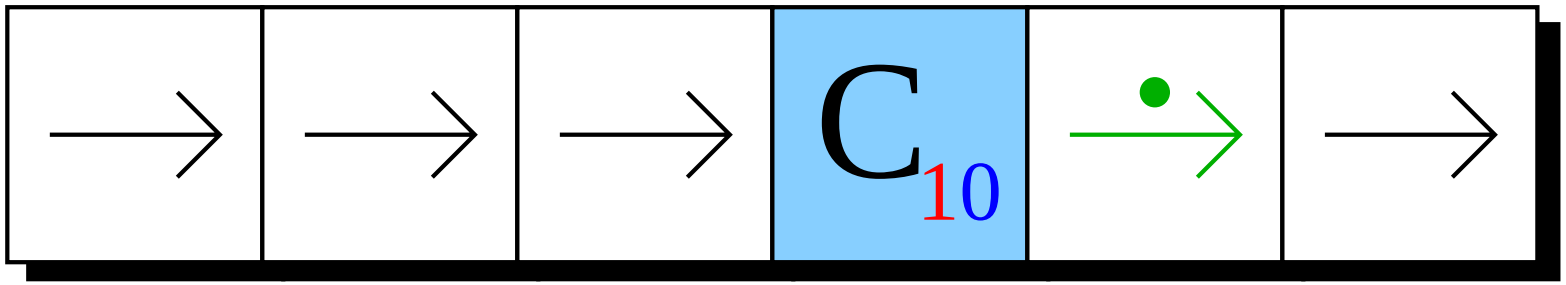
- Propriétés (1)
  - Introduction d’un double délai



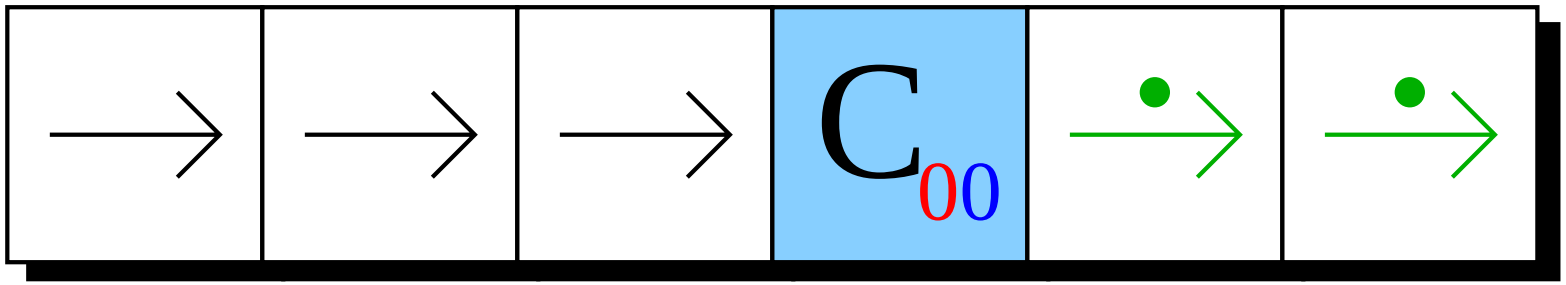
- Propriétés (1)
  - Introduction d’un double délai



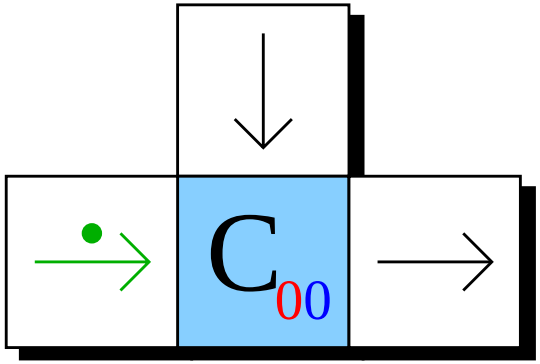
- Propriétés (1)
  - Introduction d’un double délai

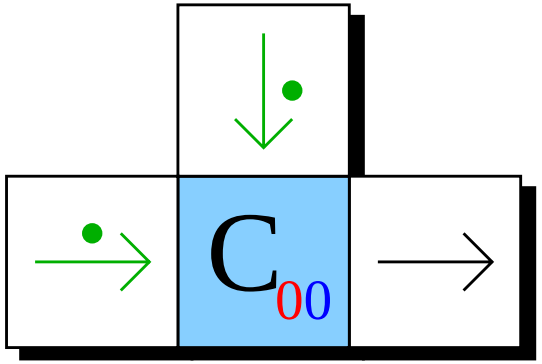


- Propriétés (1)
  - Introduction d’un double délai

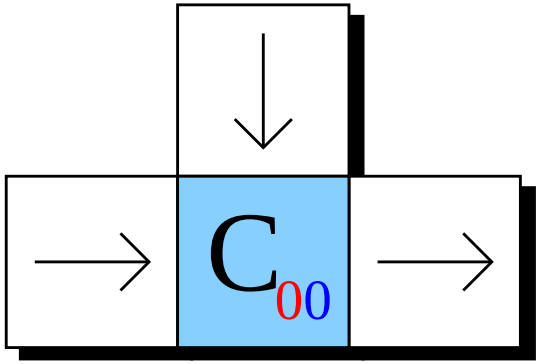


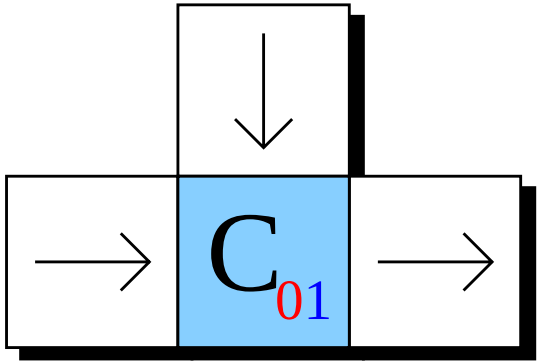
- Propriétés (2)
  - Porte logique ET



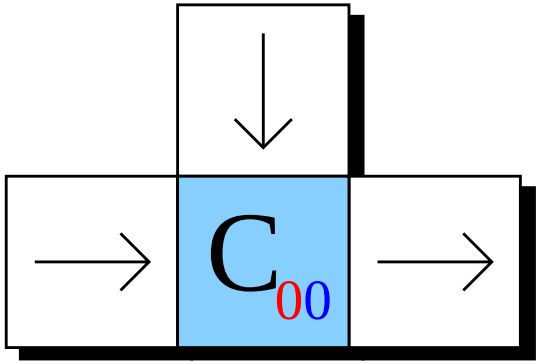


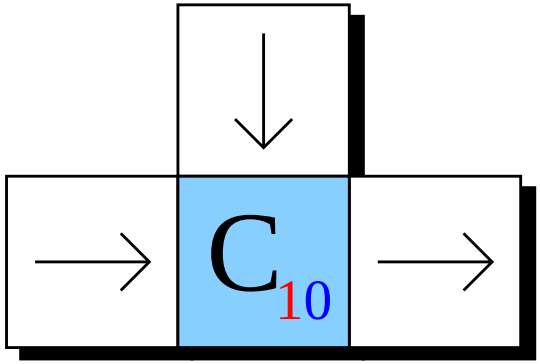
- Propriétés (2)
  - Porte logique ET



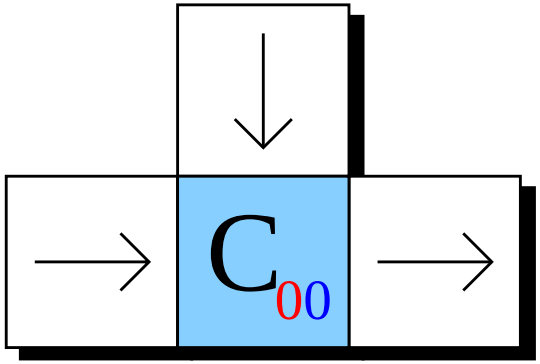


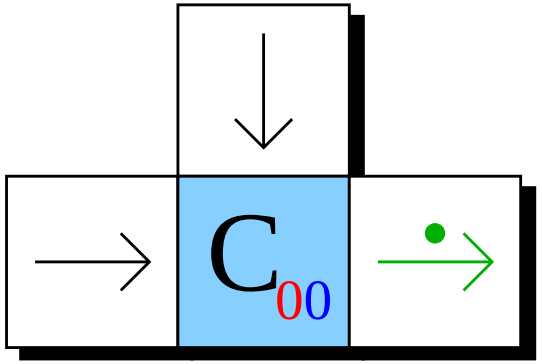
- Propriétés (2)
  - Porte logique ET



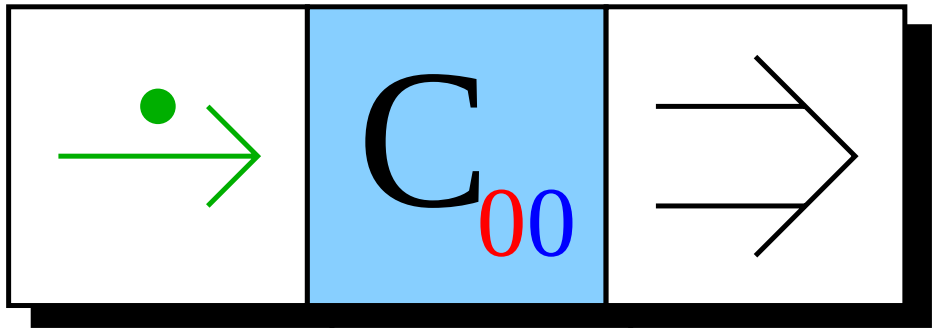


- Propriétés (2)
  - Porte logique ET

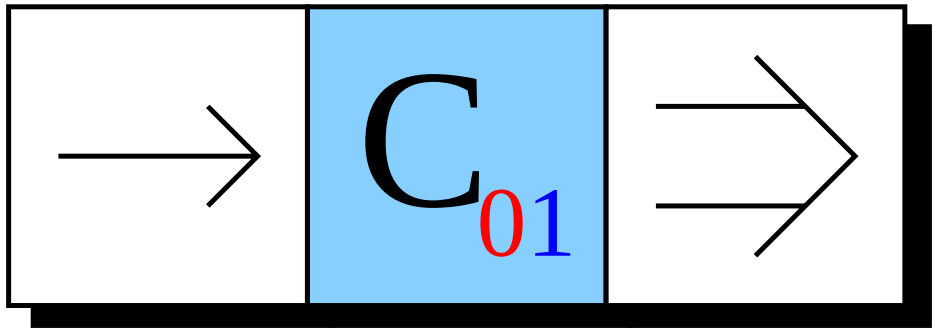




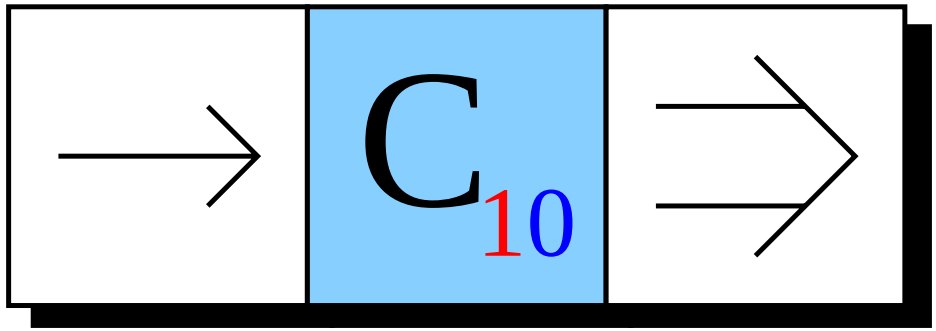
- Propriétés (3)
  - ⇒ Conversion d’une excitation ordinaire en excitation spéciale



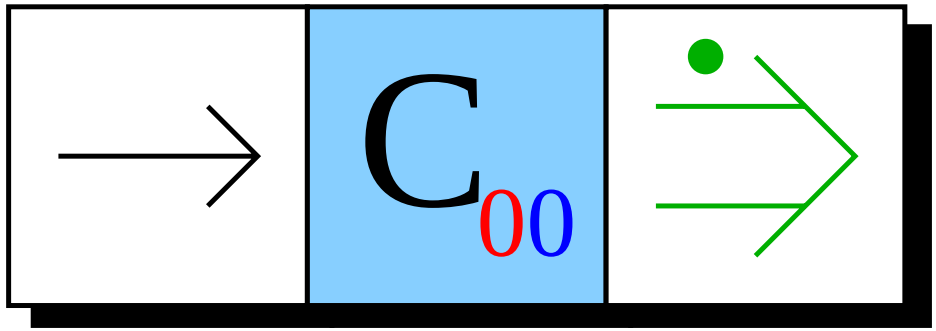
- Propriétés (3)
  - ⇒ Conversion d’une excitation ordinaire en excitation spéciale



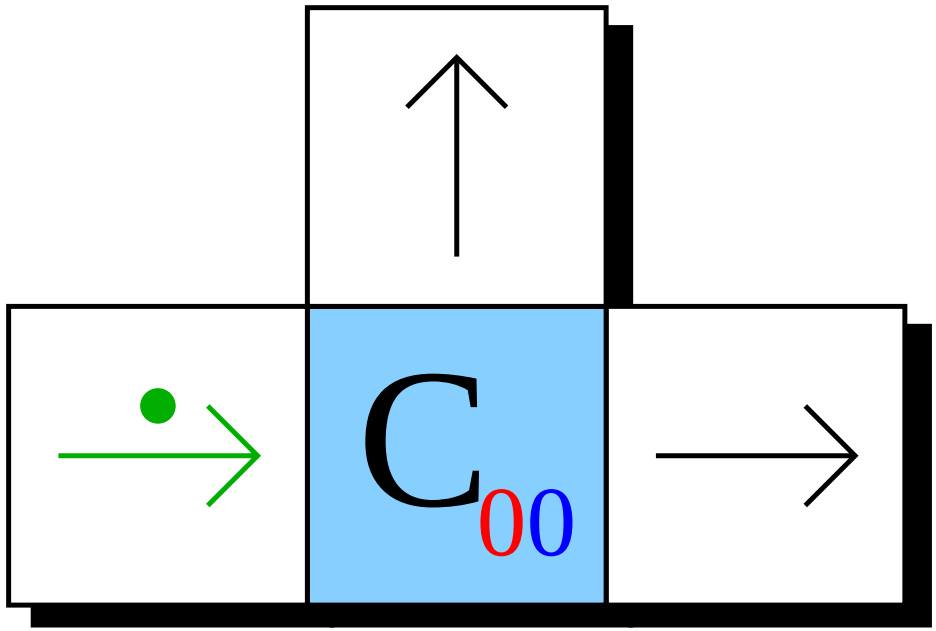
- Propriétés (3)
  - ⇒ Conversion d’une excitation ordinaire en excitation spéciale



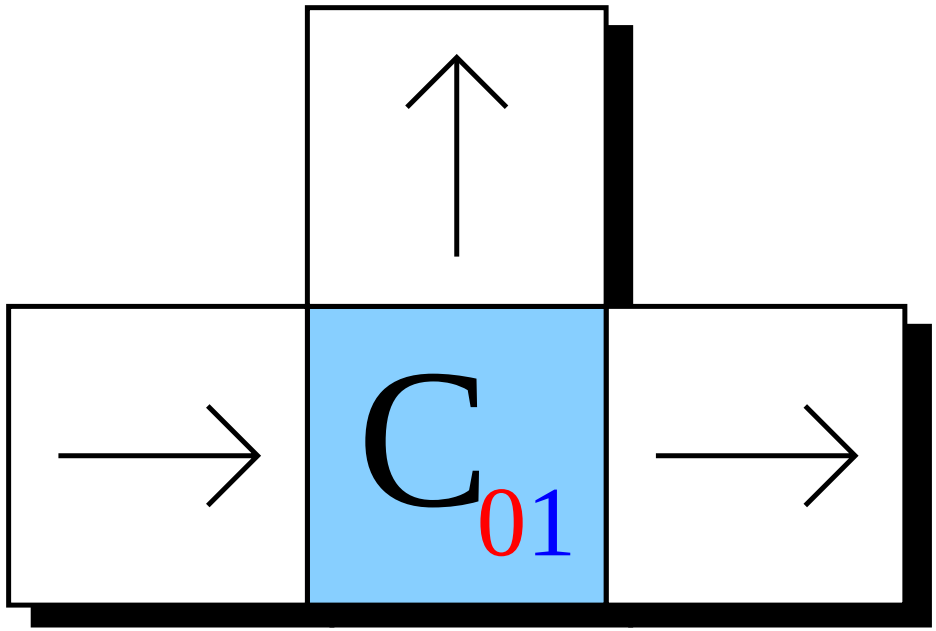
- Propriétés (3)
  - ⇒ Conversion d’une excitation ordinaire en excitation spéciale



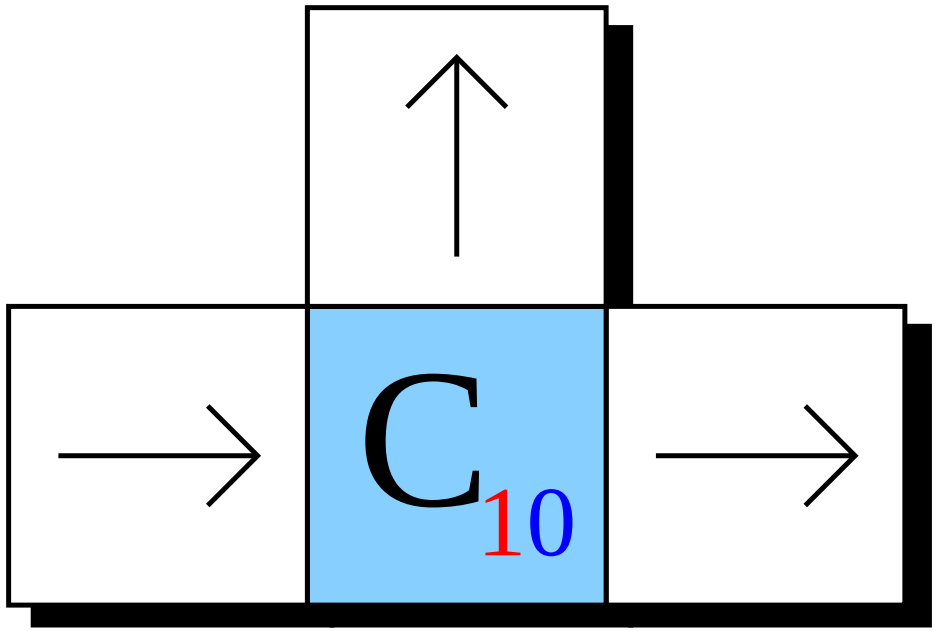
- Propriétés (4)
  - *Fan-out*



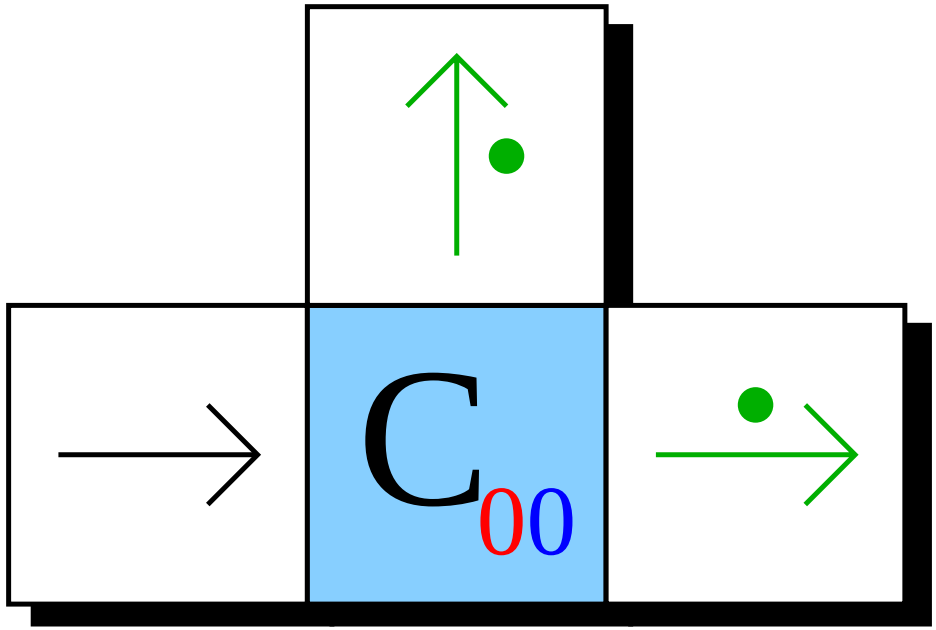
- Propriétés (4)
  - *Fan-out*



- Propriétés (4)
  - *Fan-out*

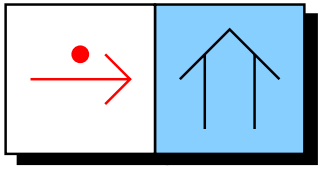


- Propriétés (4)
  - *Fan-out*

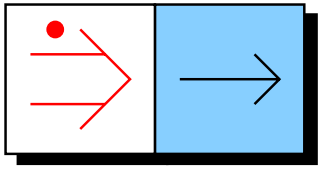


Destruction

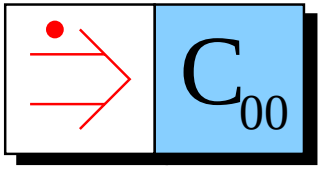
Etat de transmission spécial



Etat de transmission ordinaire

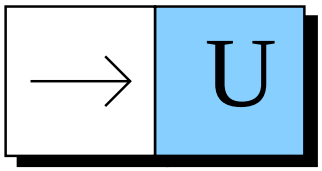


Etat confluent

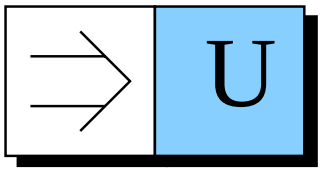


Destruction

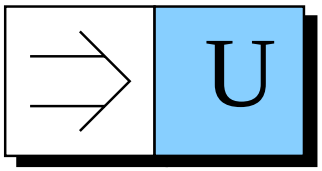
Etat de transmission spécial



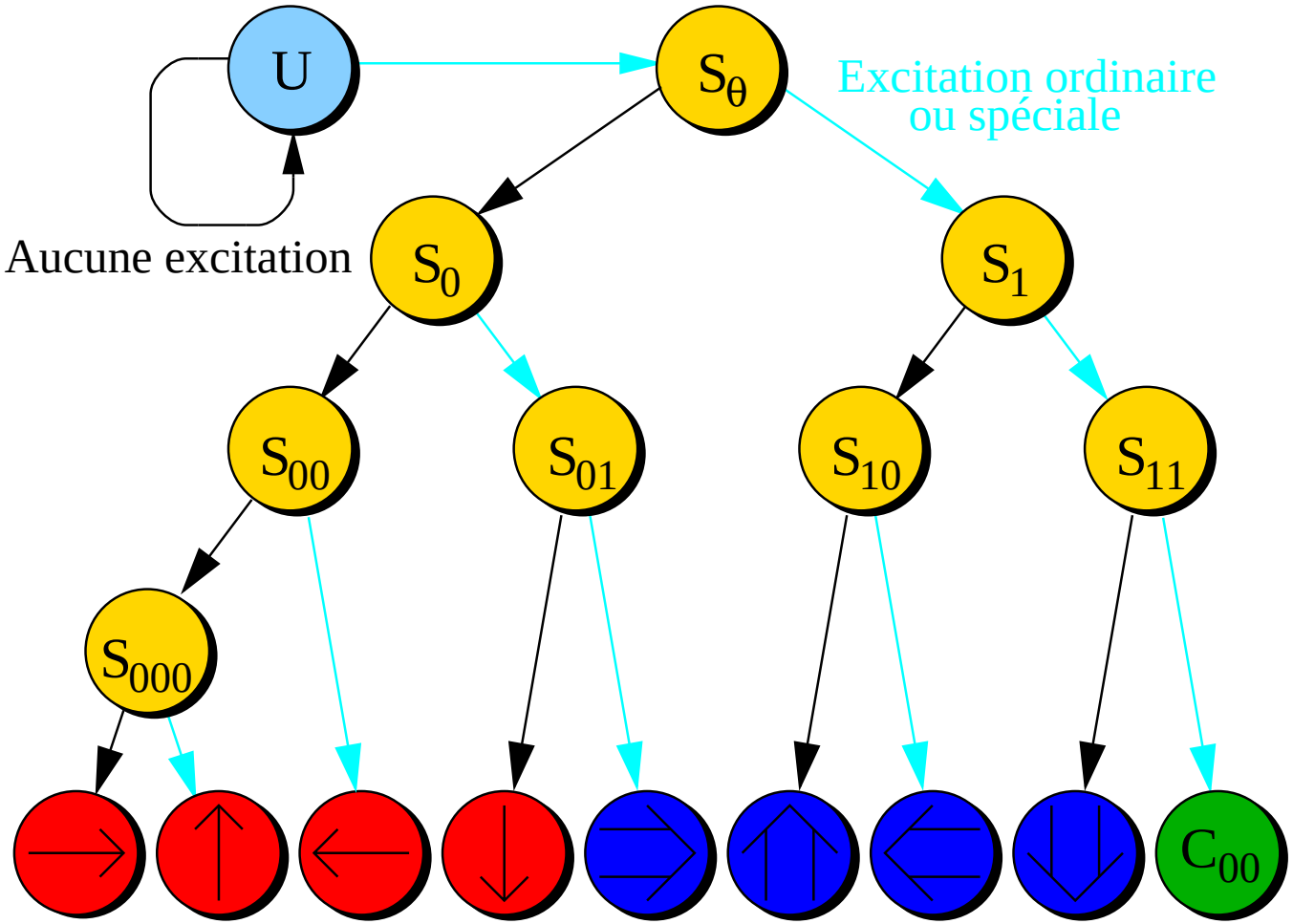
Etat de transmission ordinaire



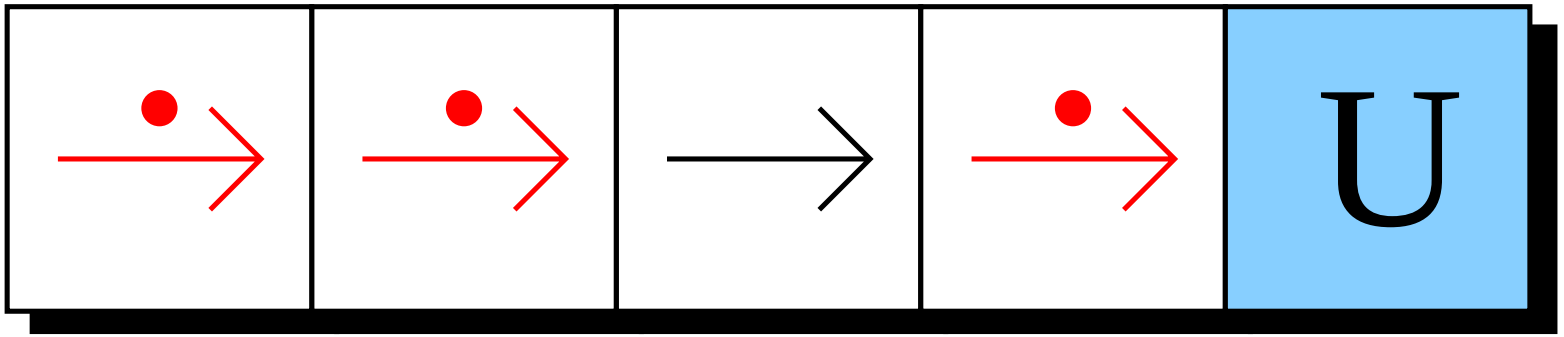
Etat confluent



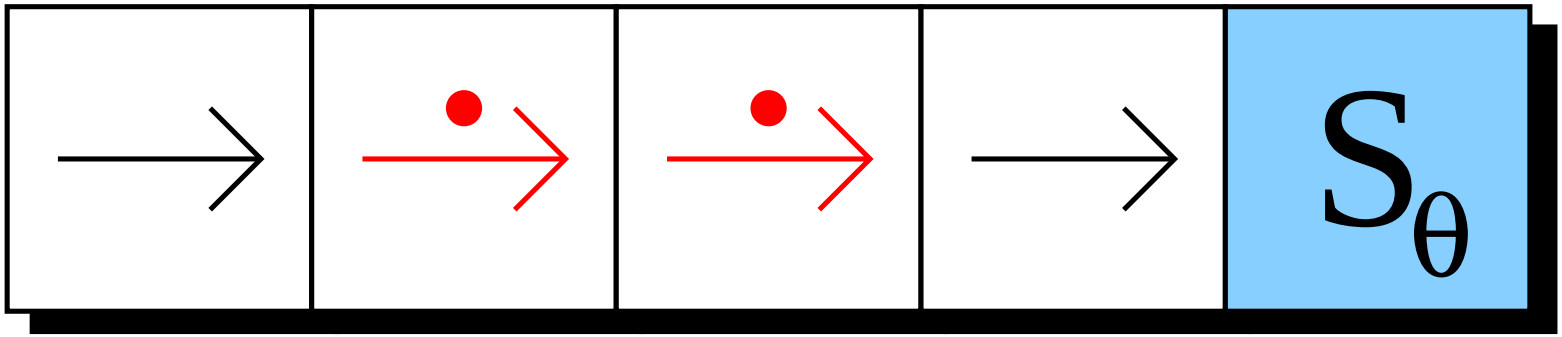
Etats sensitifs



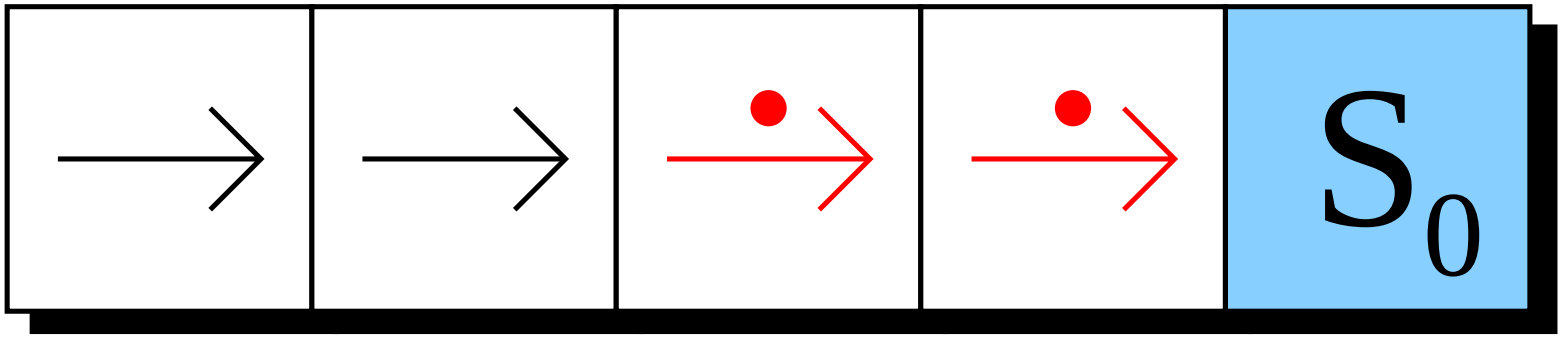
- Exemple



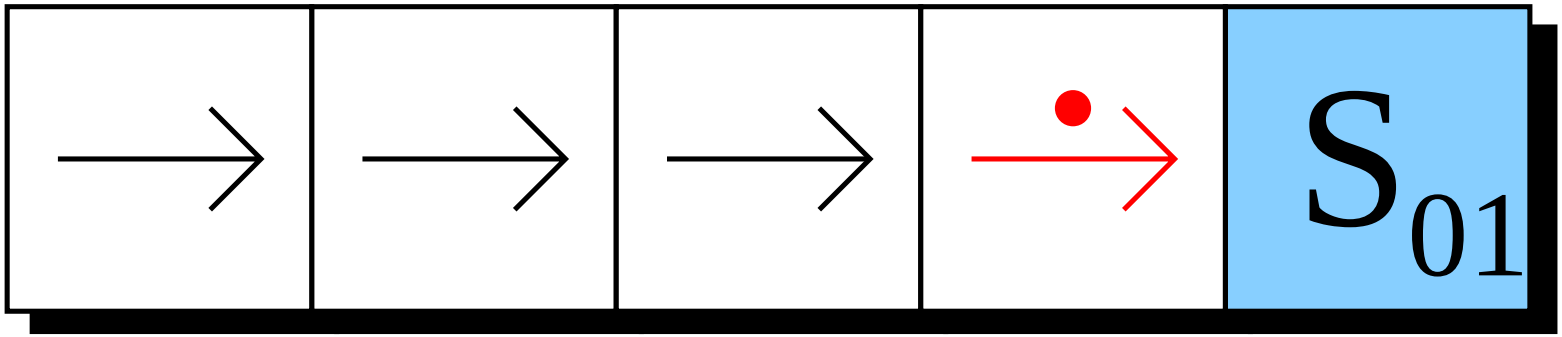
- Exemple



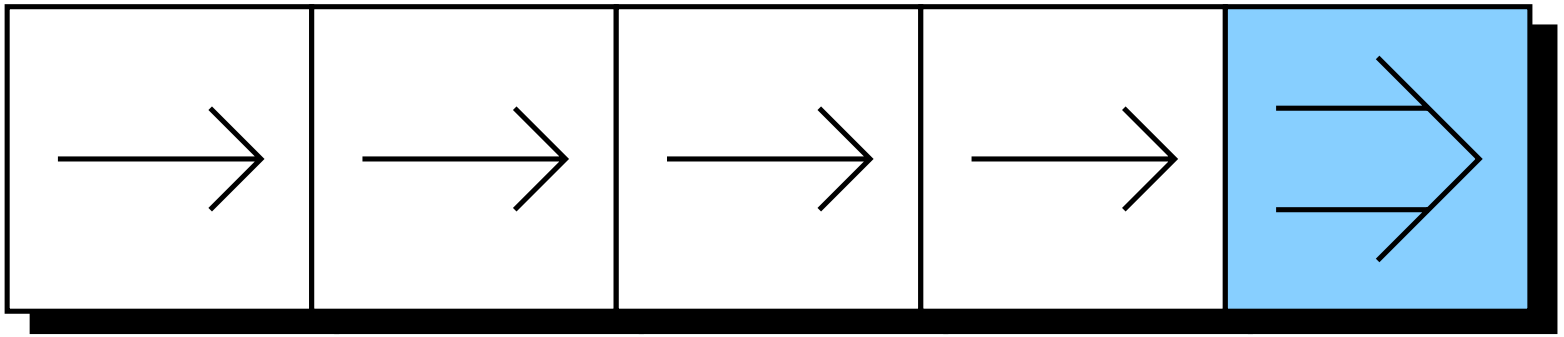
- Exemple



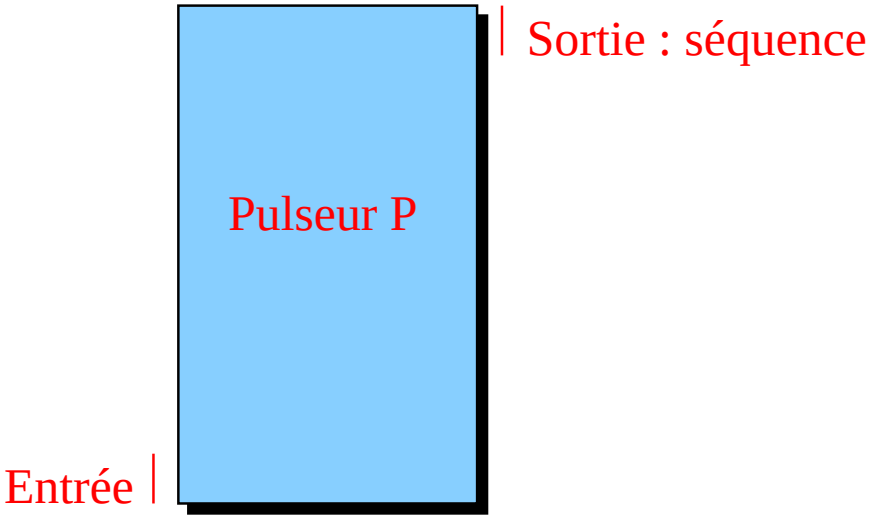
- Exemple



- Exemple

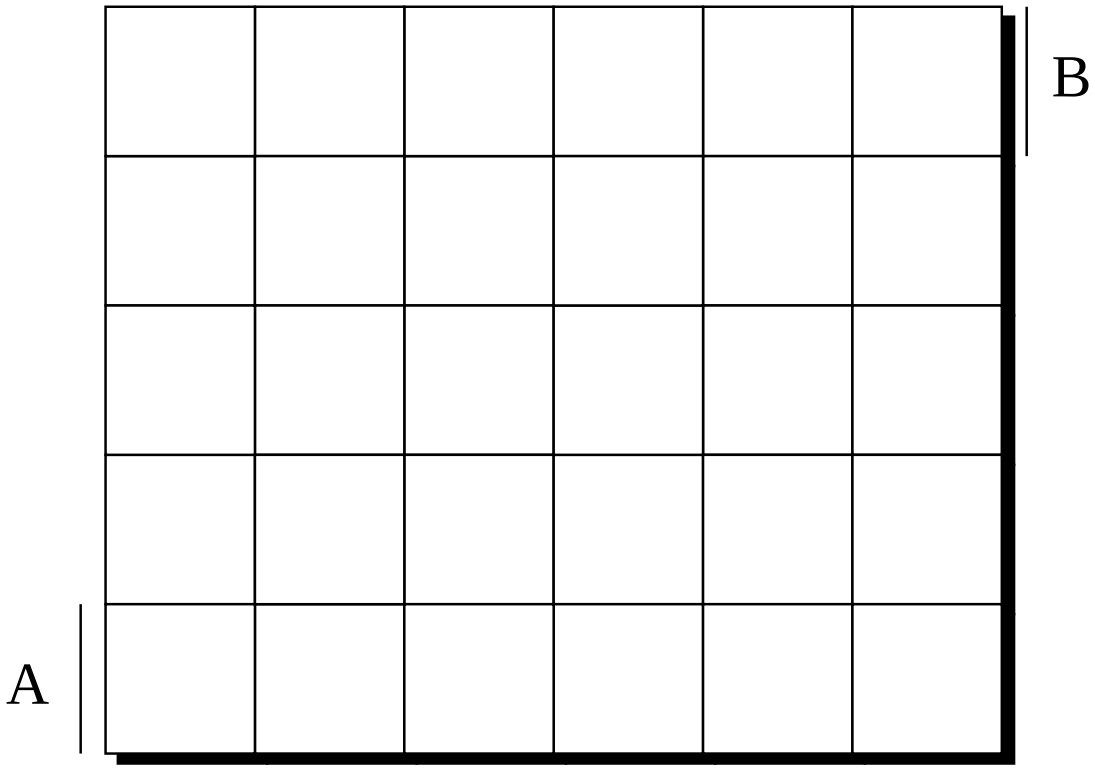


Le pulseur

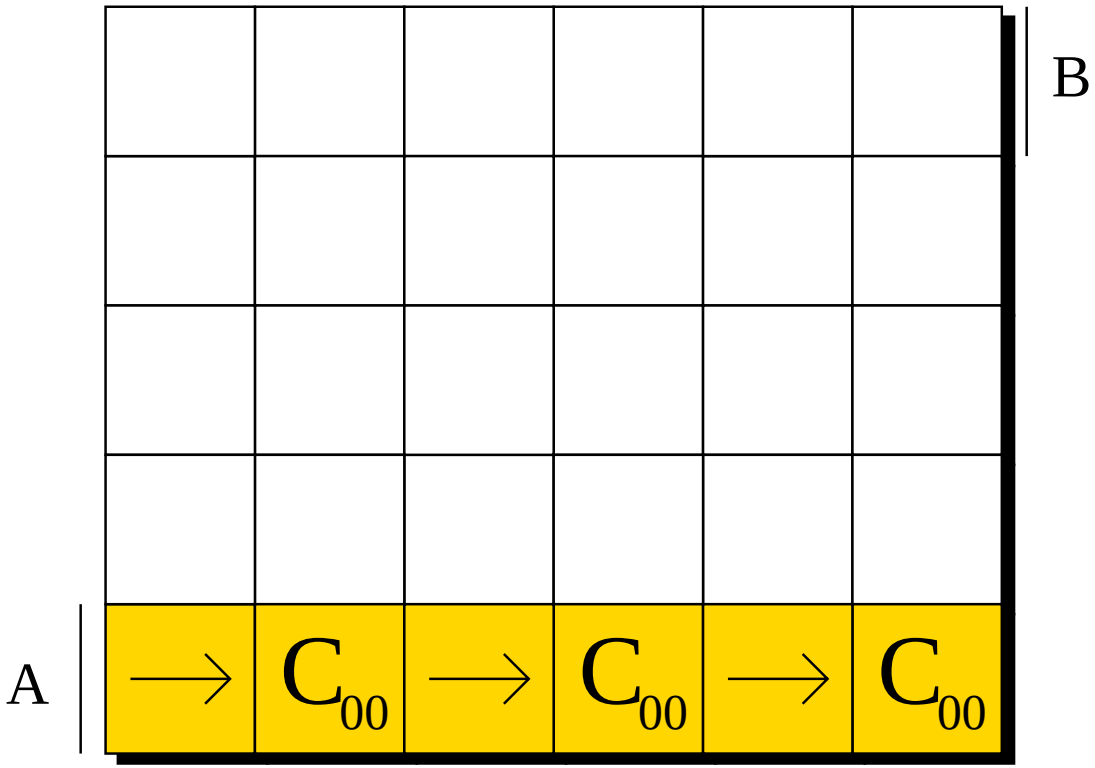


- Génération d'une séquence de *0* et de *1*
  - k = nombre de *1*
  - u = nombre de *0*
- Taille du pulseur
  - Largeur : $2 \cdot k$ cellules
  - Hauteur : $u + 2$ cellules
  - Si un seul *0* dans la séquence : $u = 2$

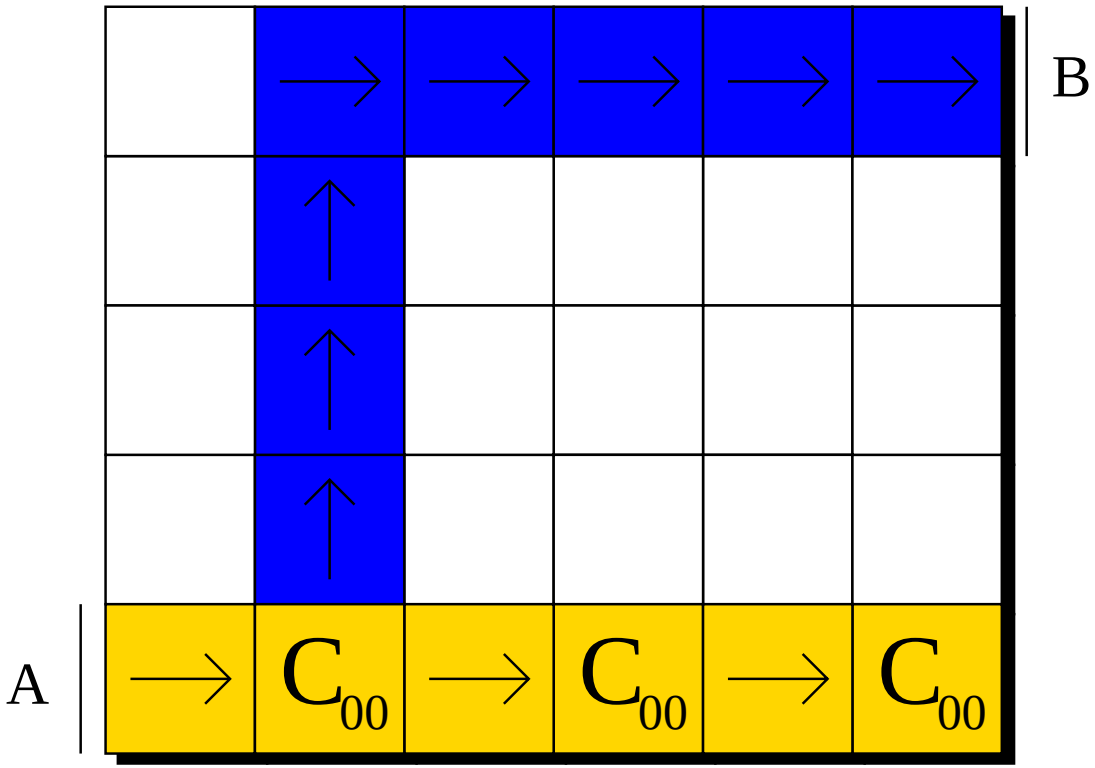
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



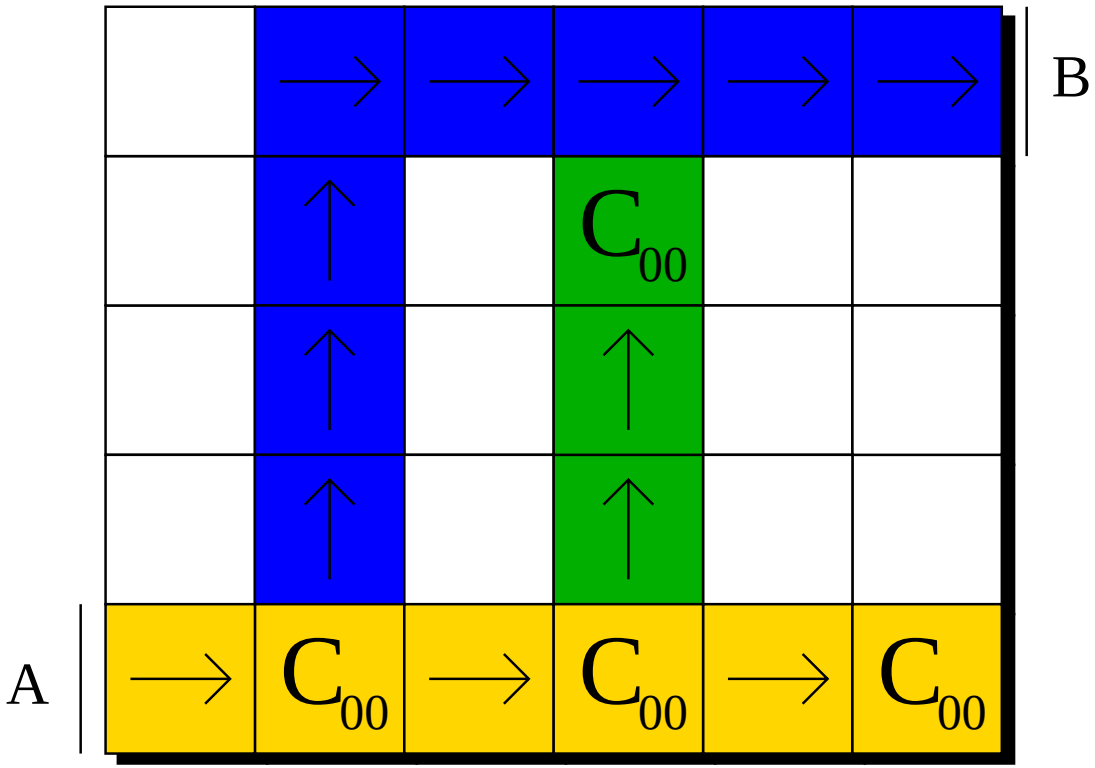
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



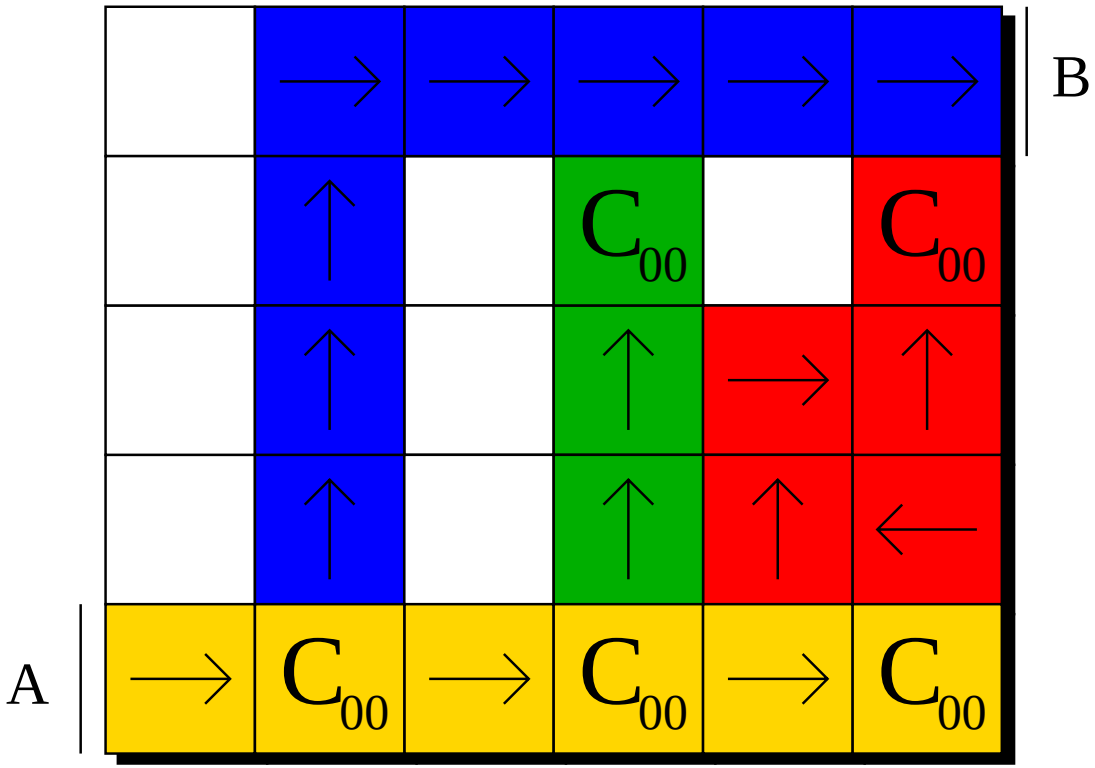
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



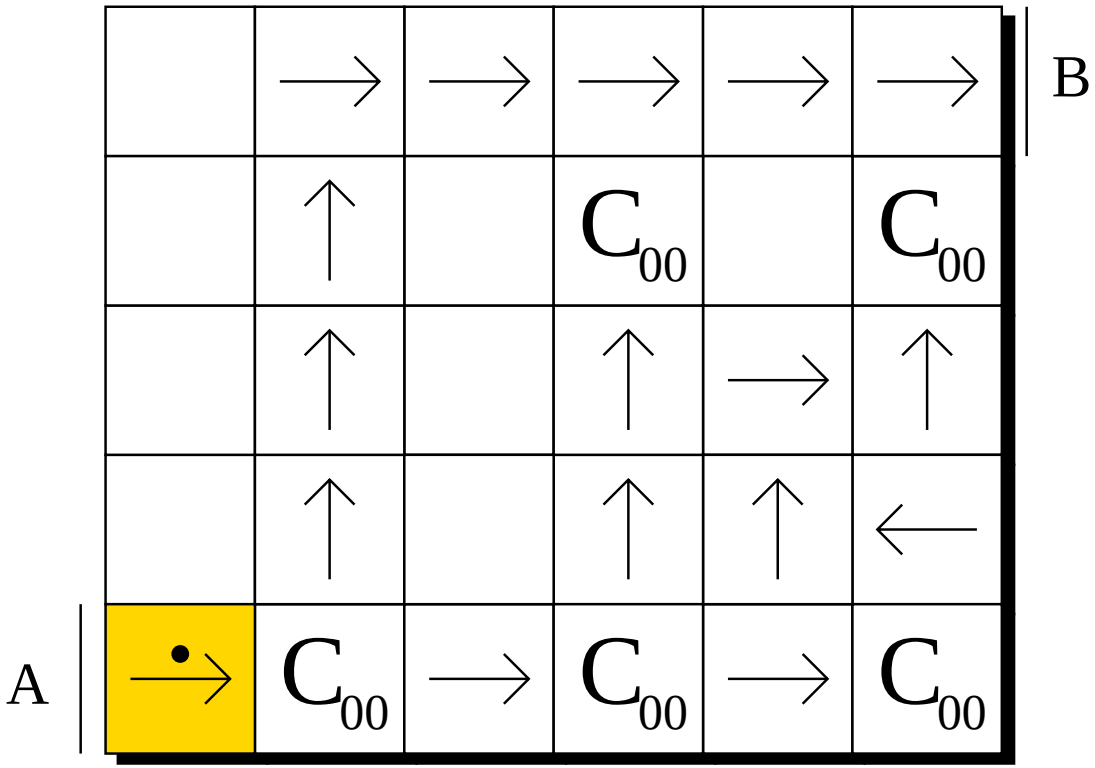
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



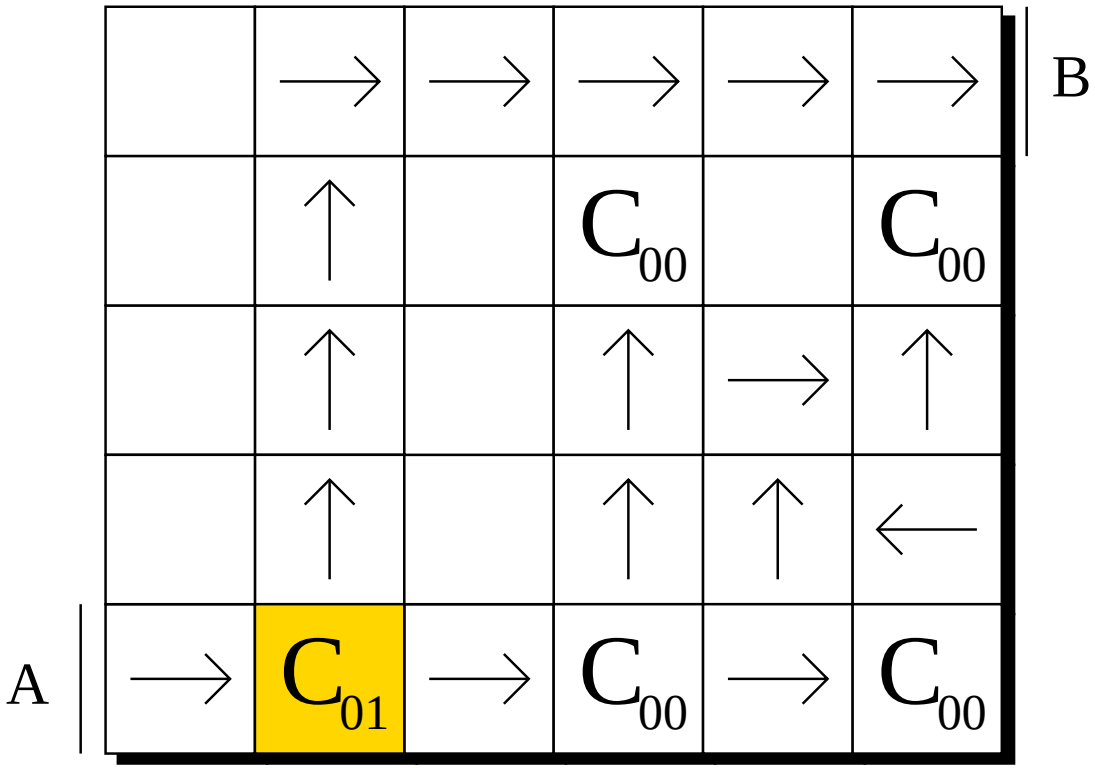
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



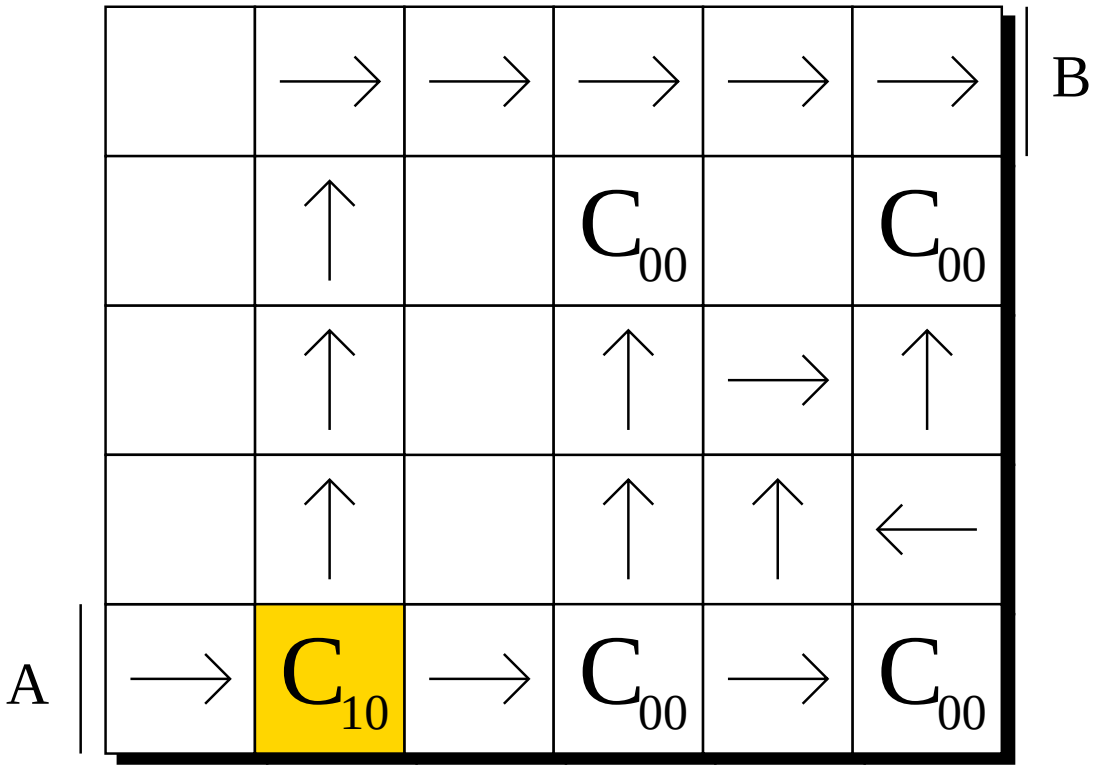
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



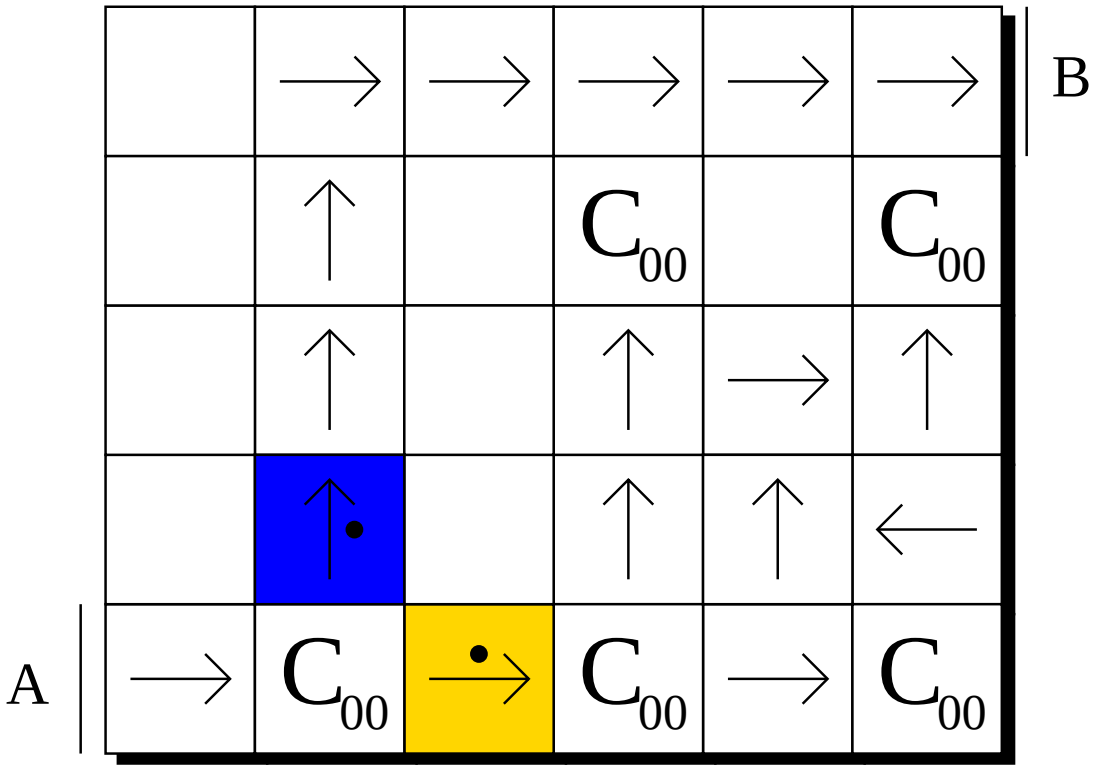
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



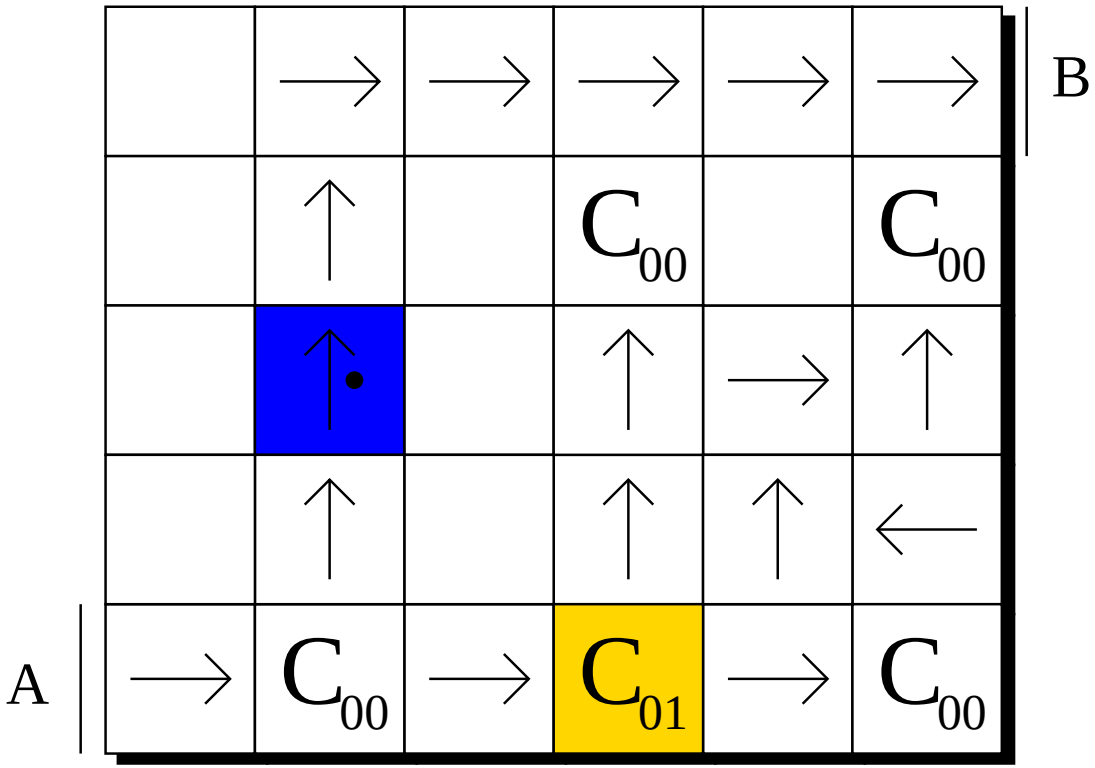
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



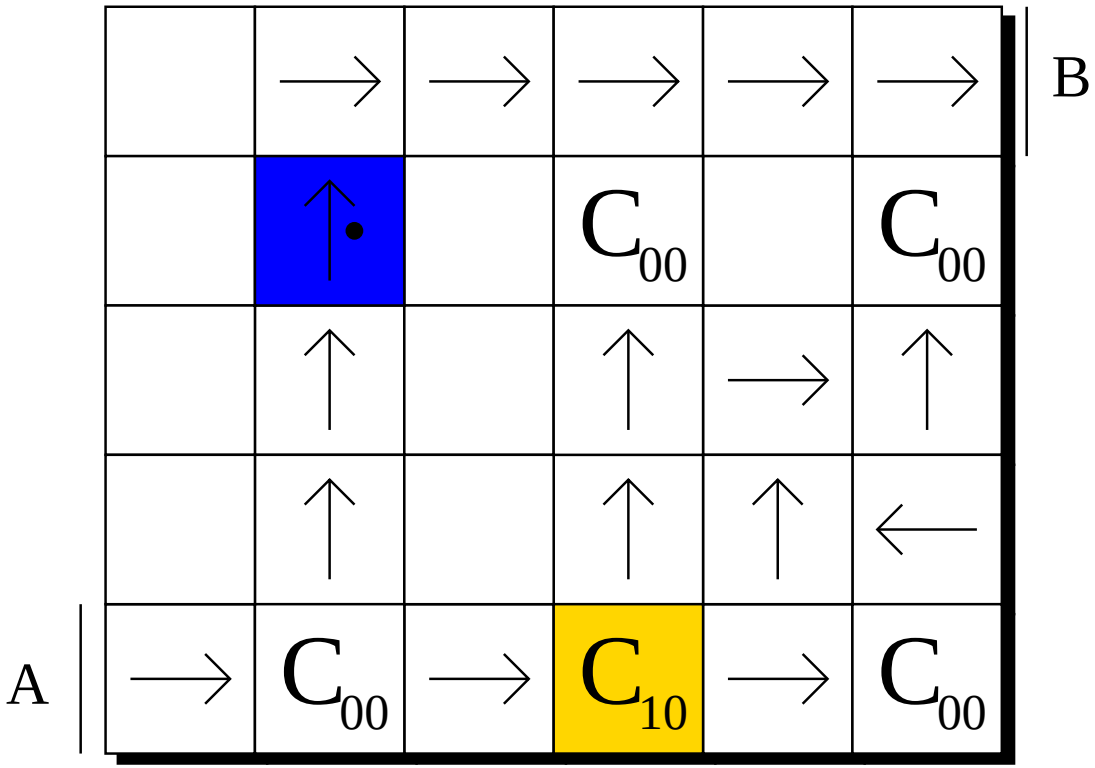
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



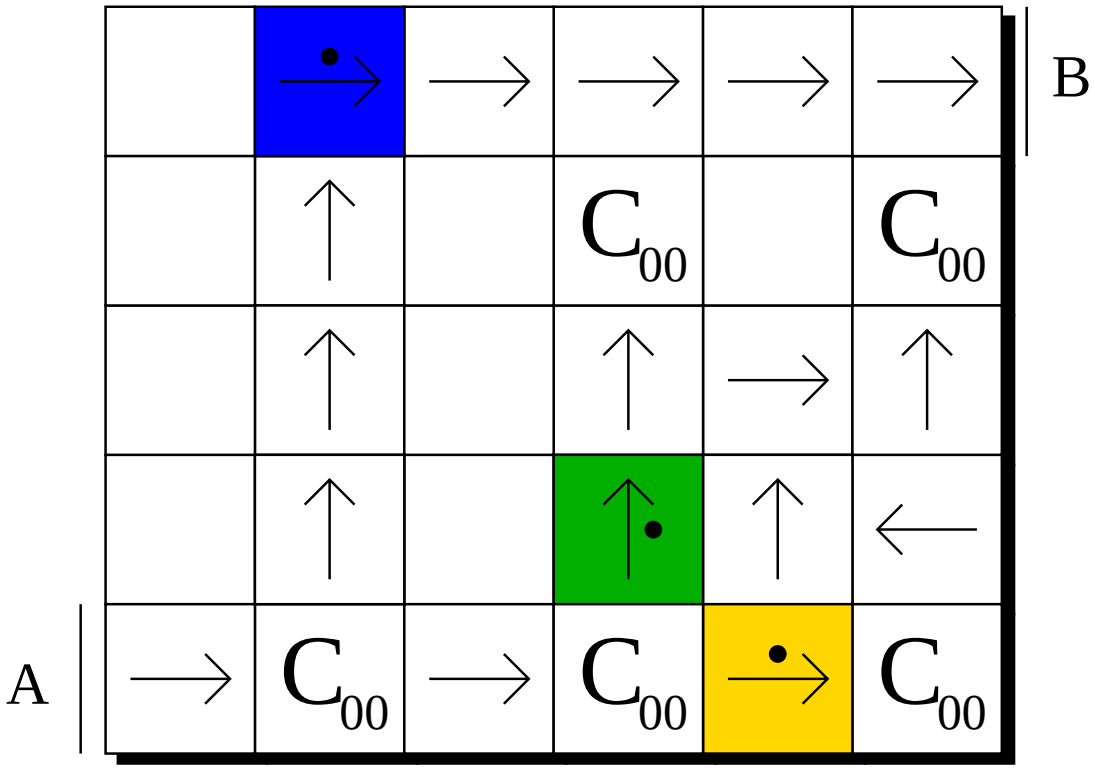
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



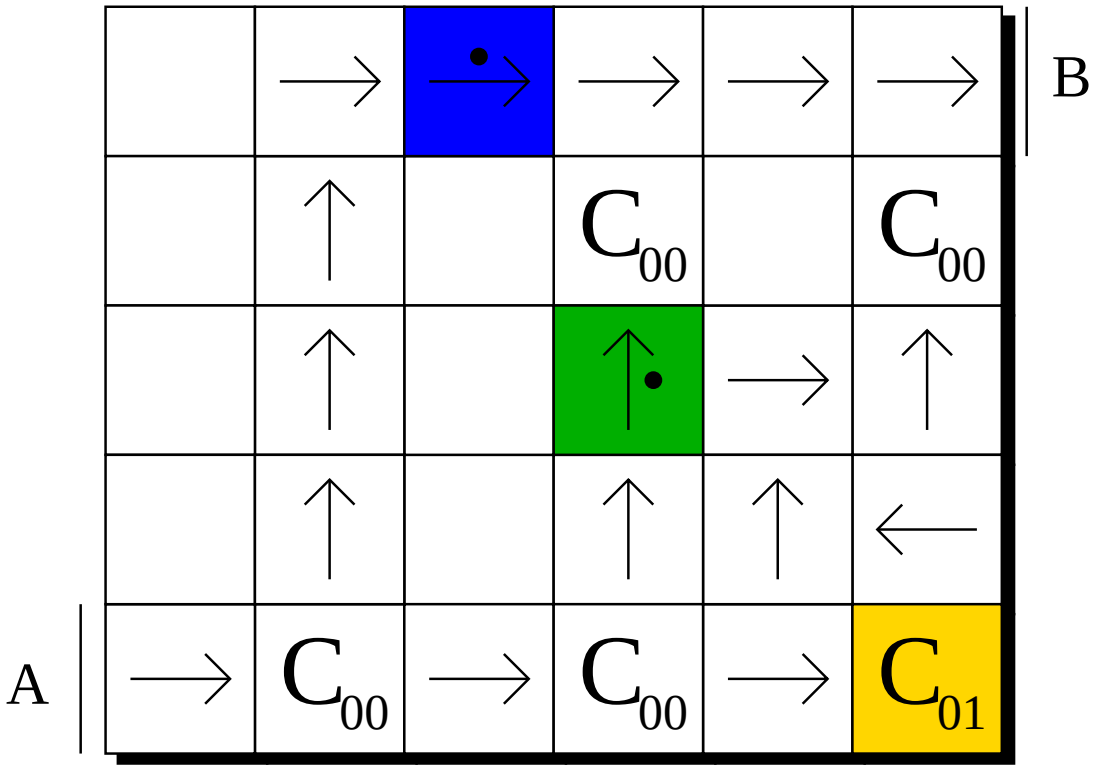
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



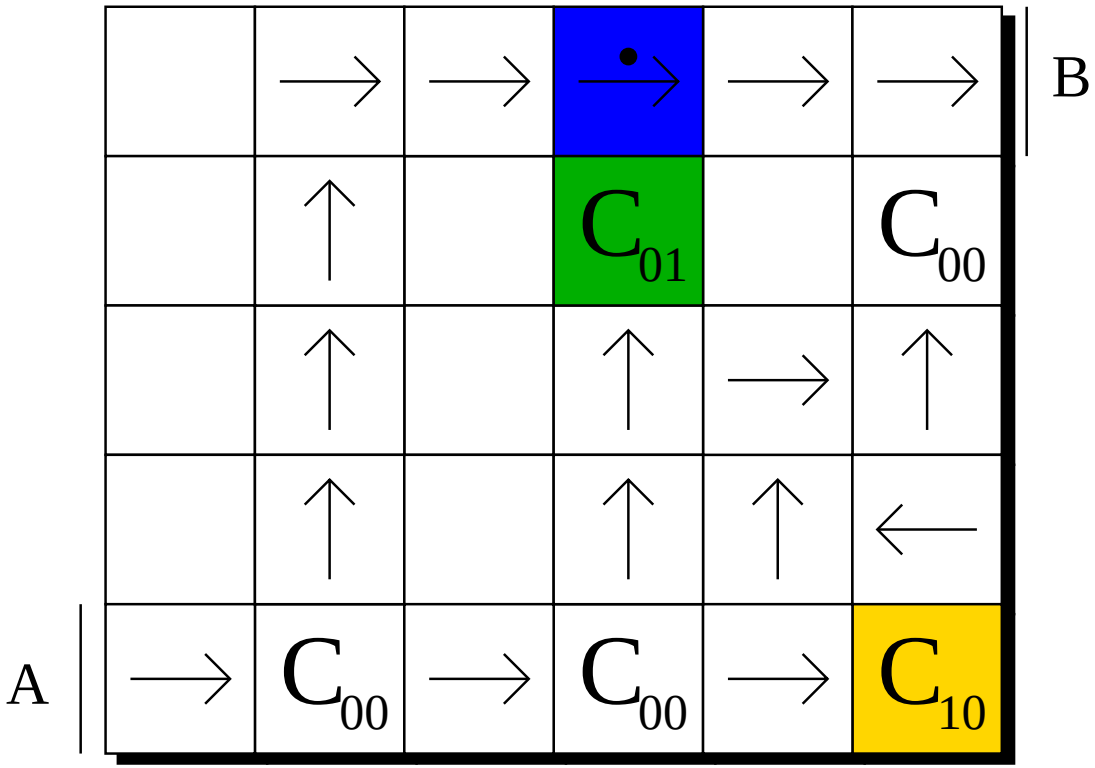
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



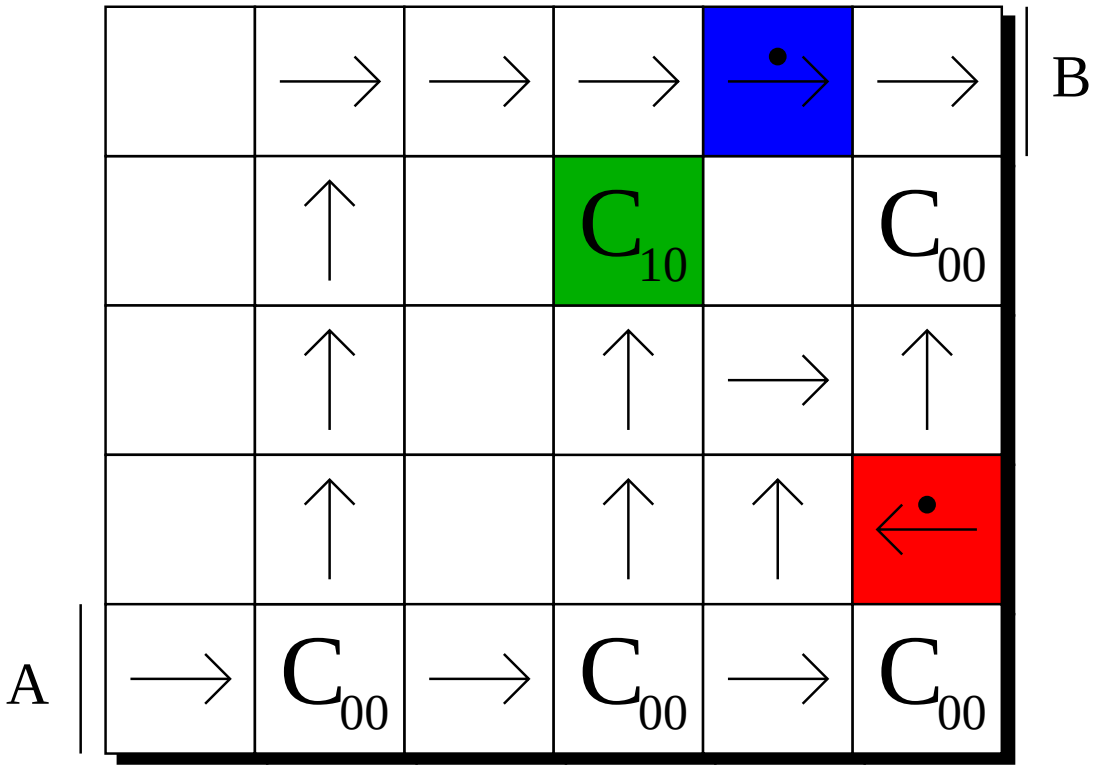
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



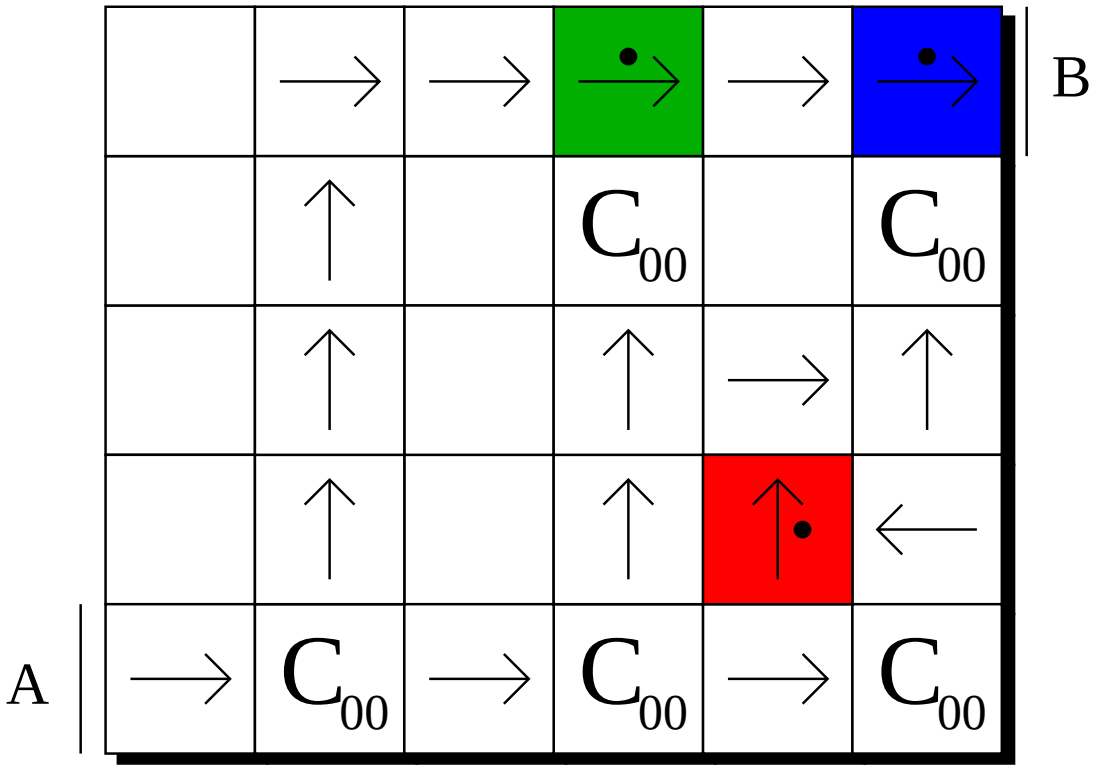
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



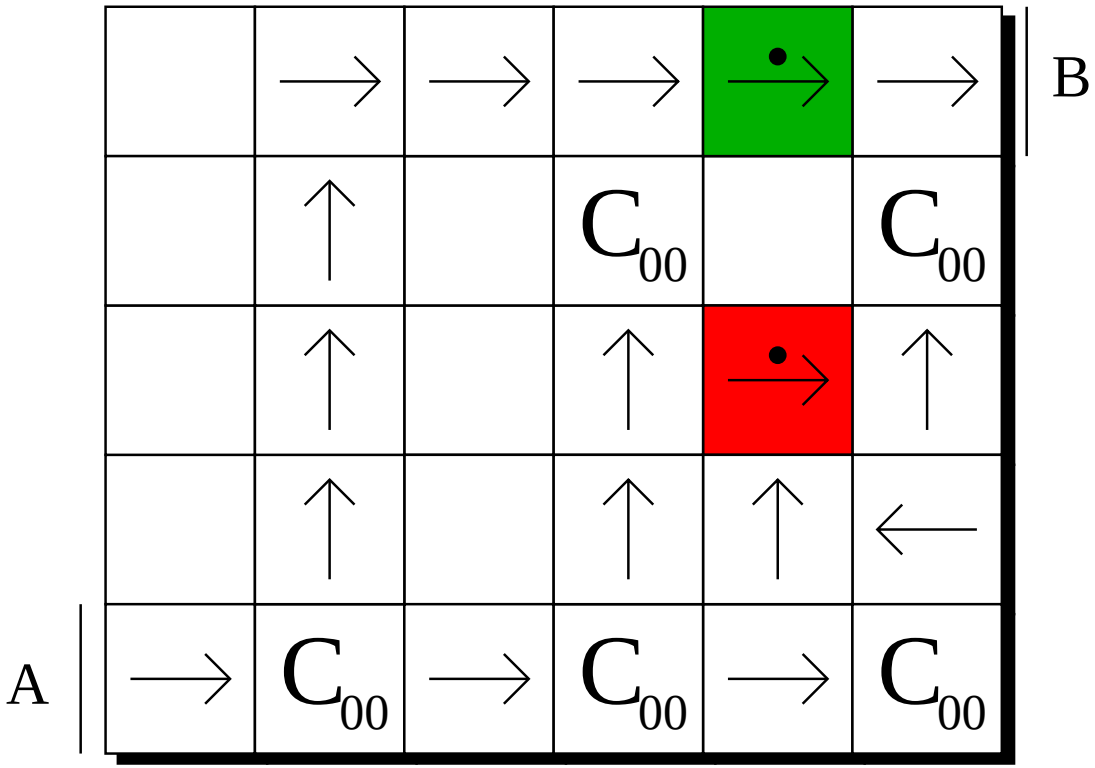
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



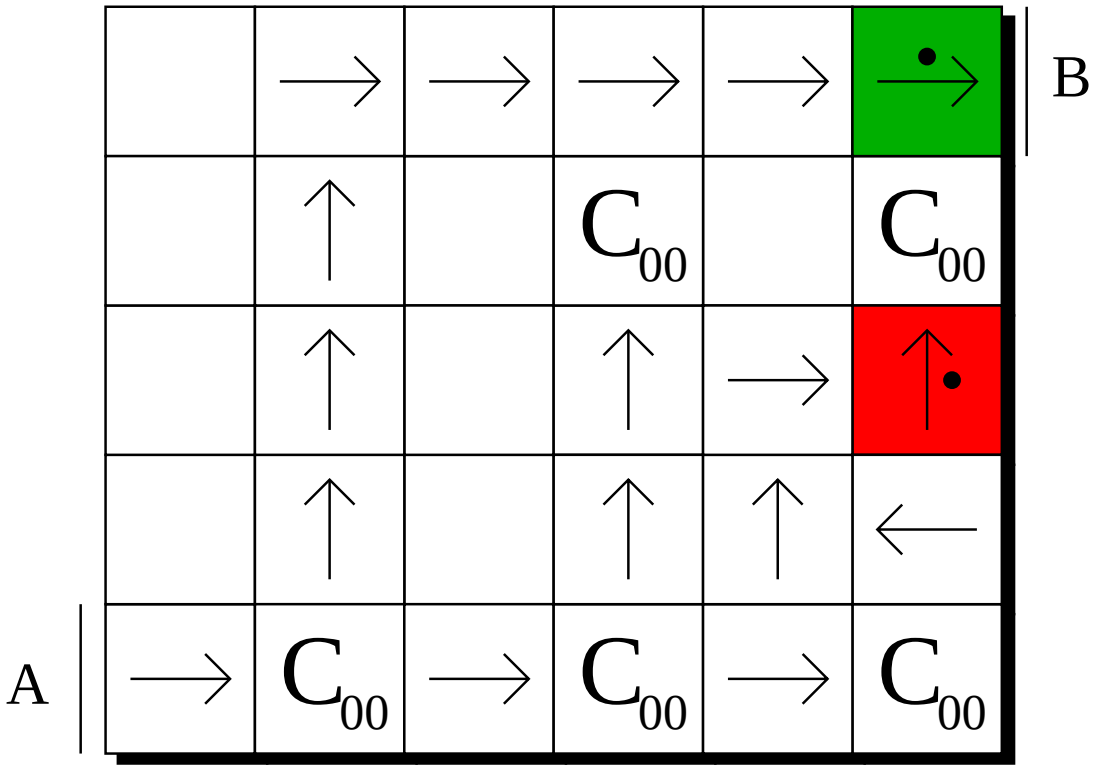
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



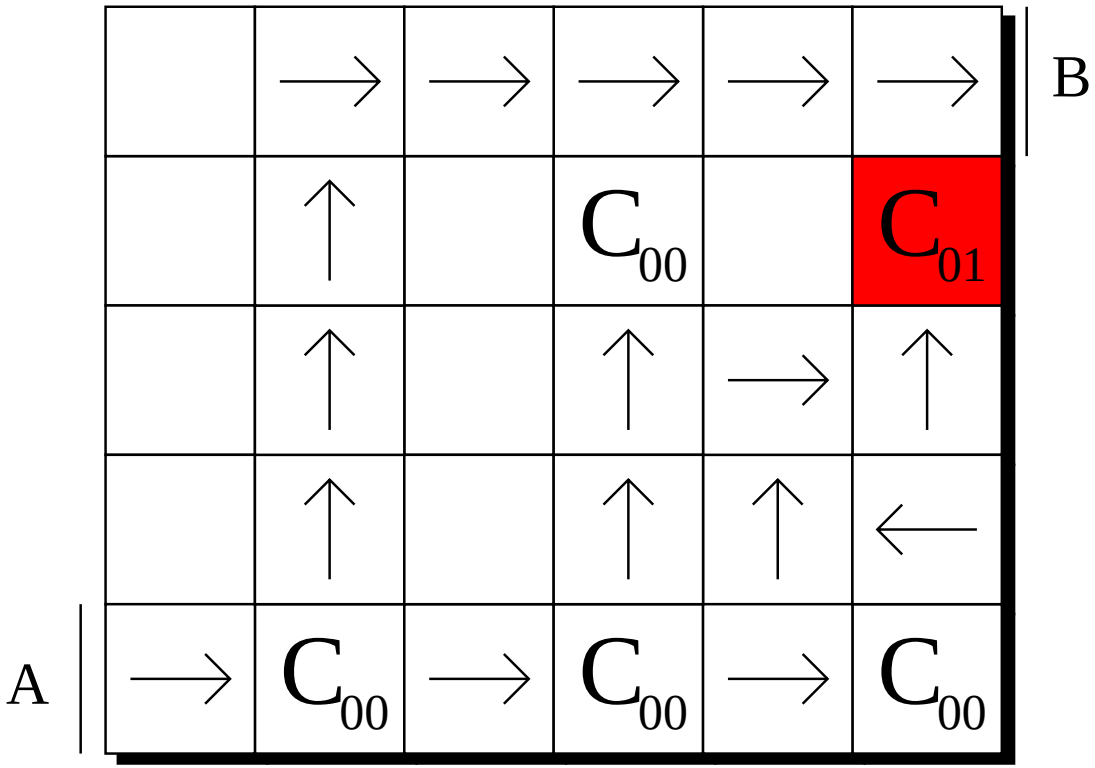
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



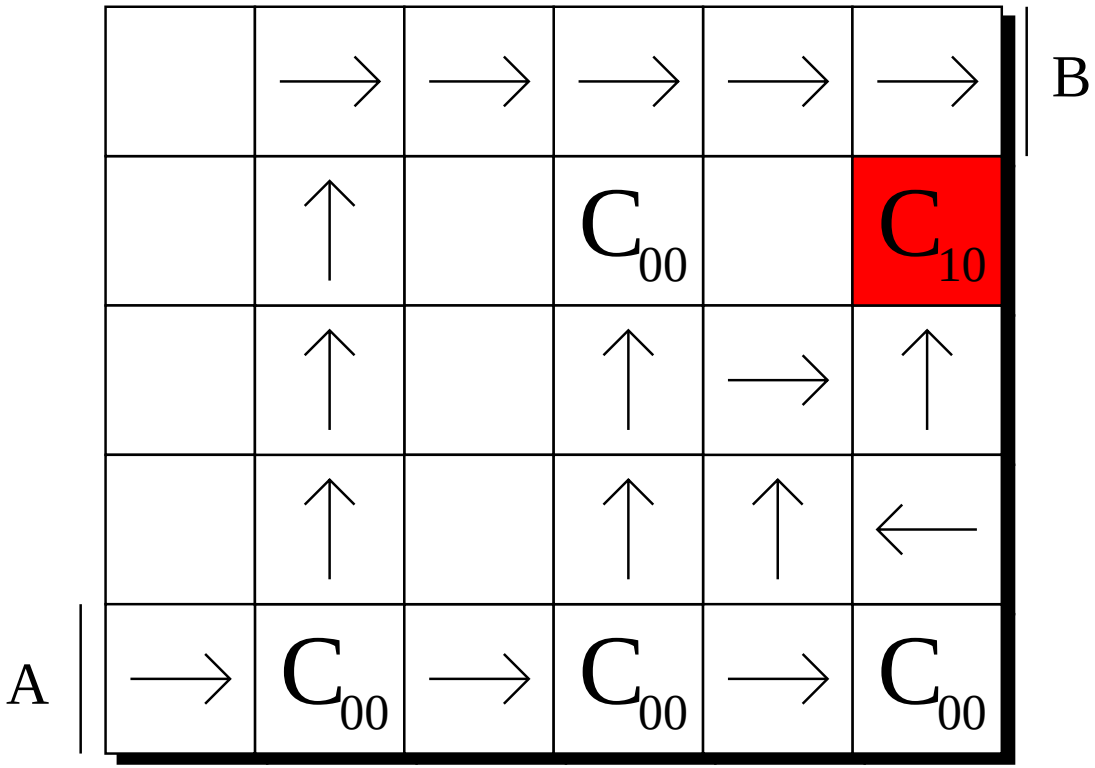
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



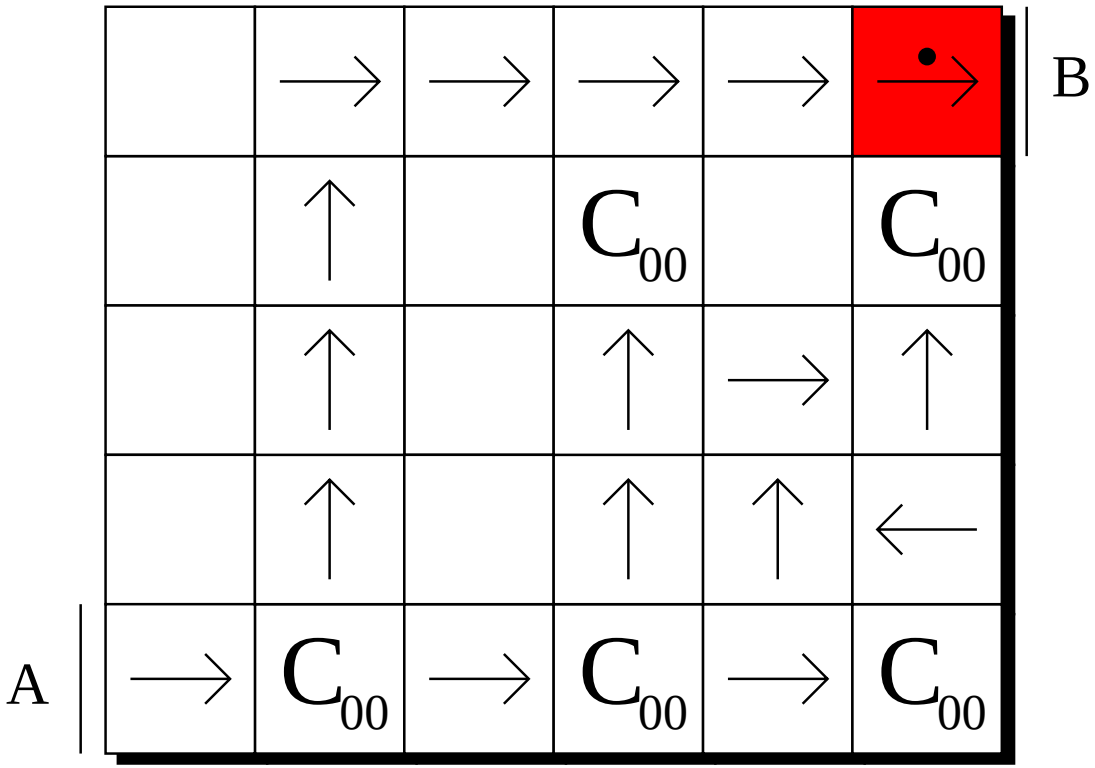
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



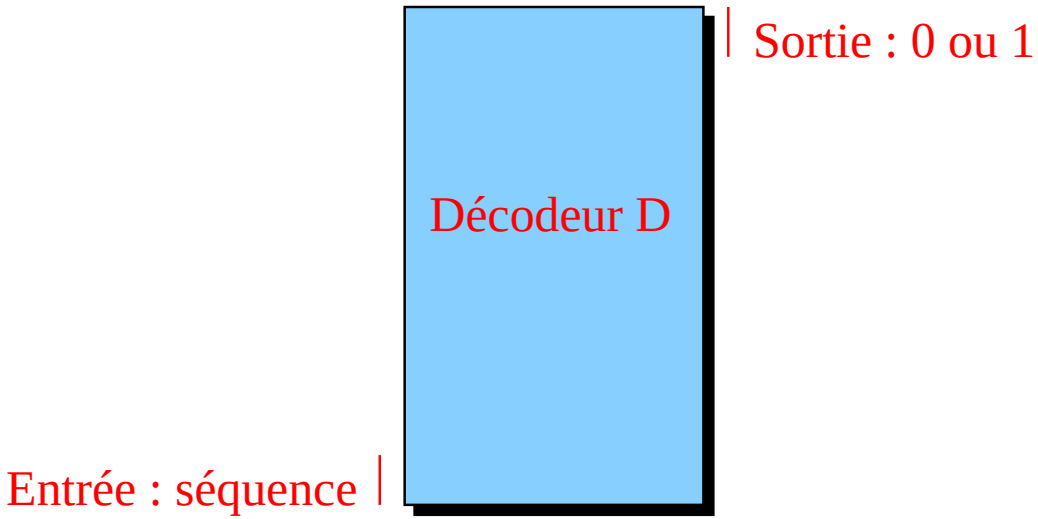
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



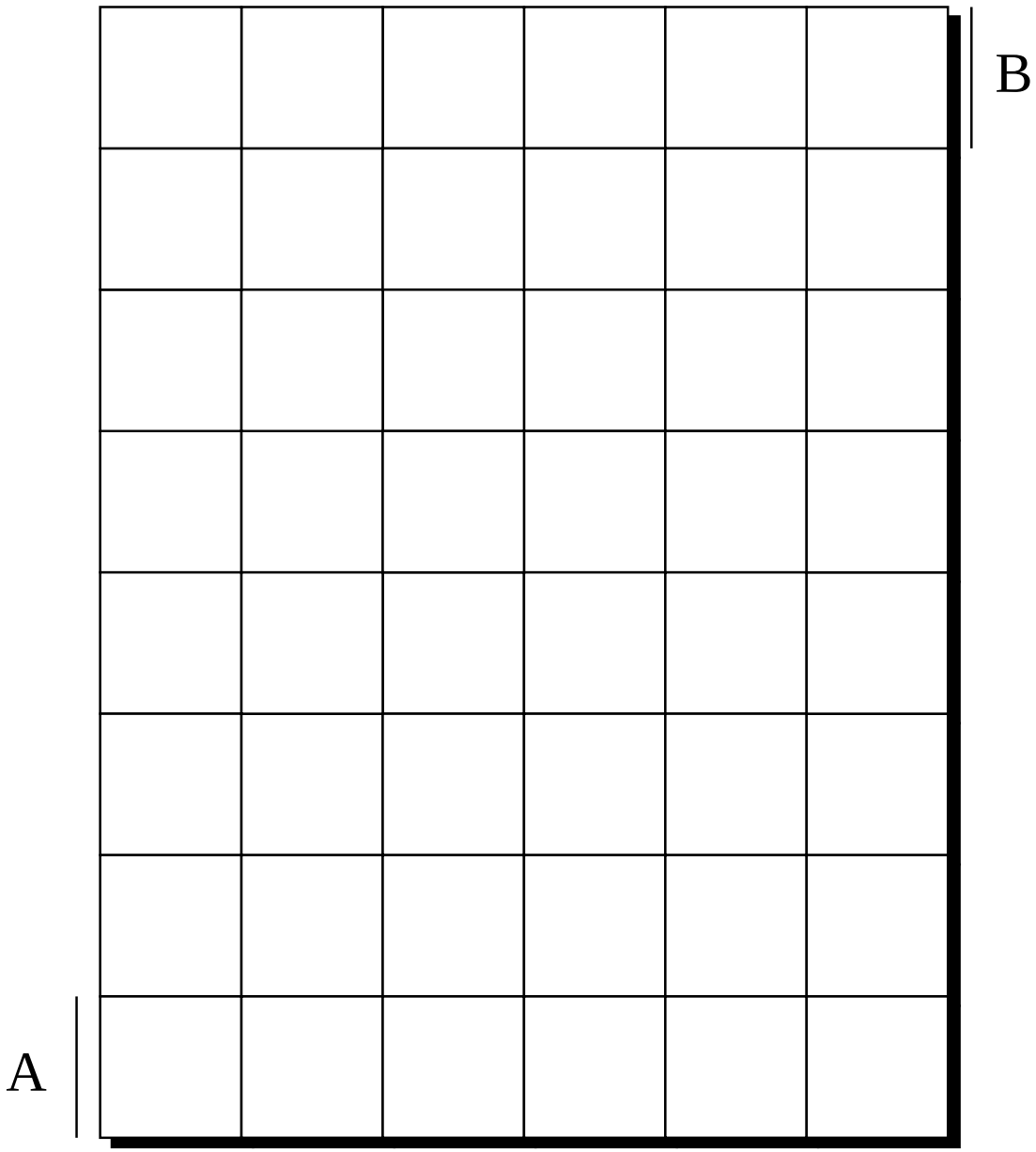
- Pulseur P(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k = 6$ cellules
  - $u = 3 \Rightarrow$ Hauteur $= u + 2 = 5$ cellules



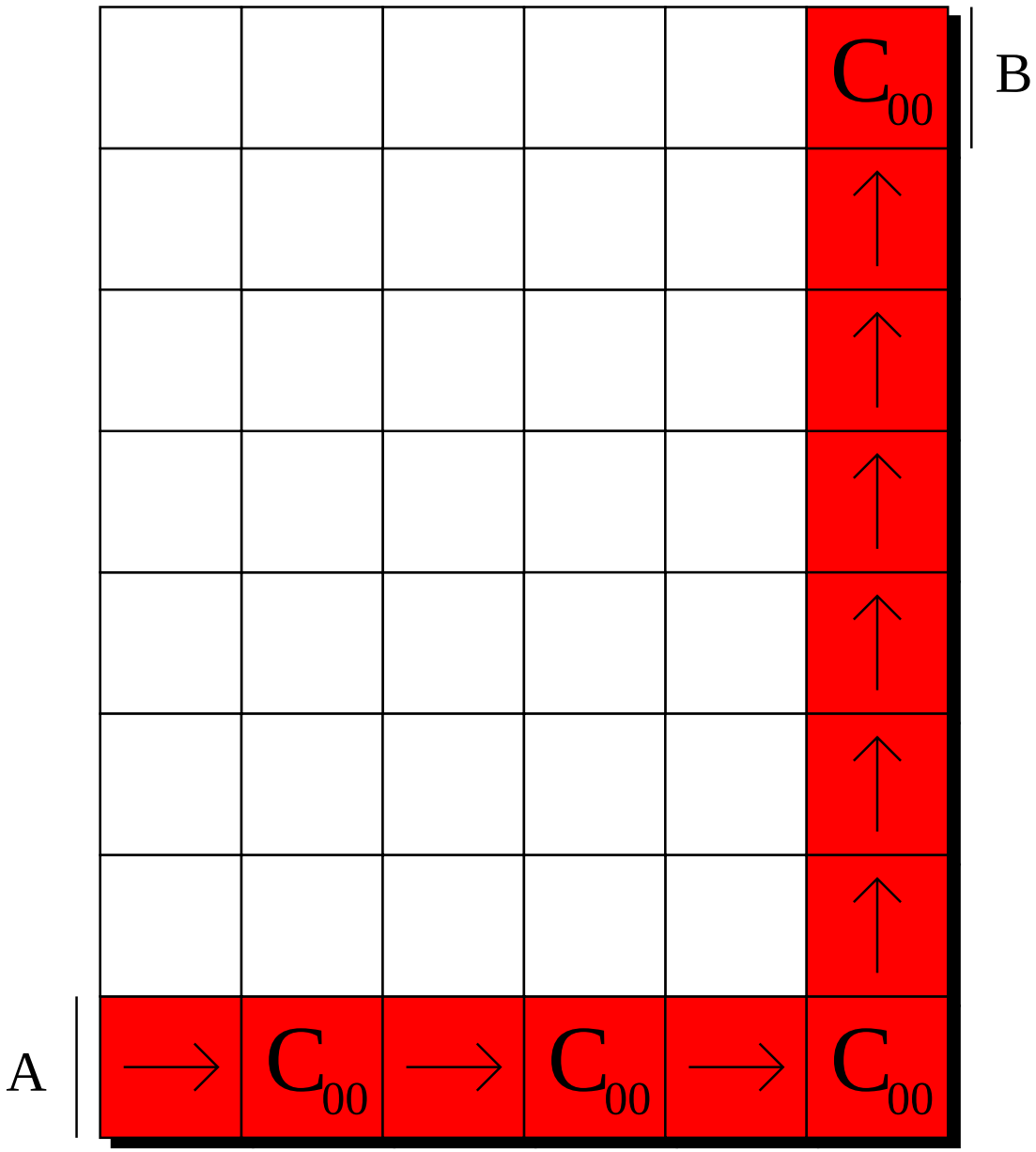
Le décodeur



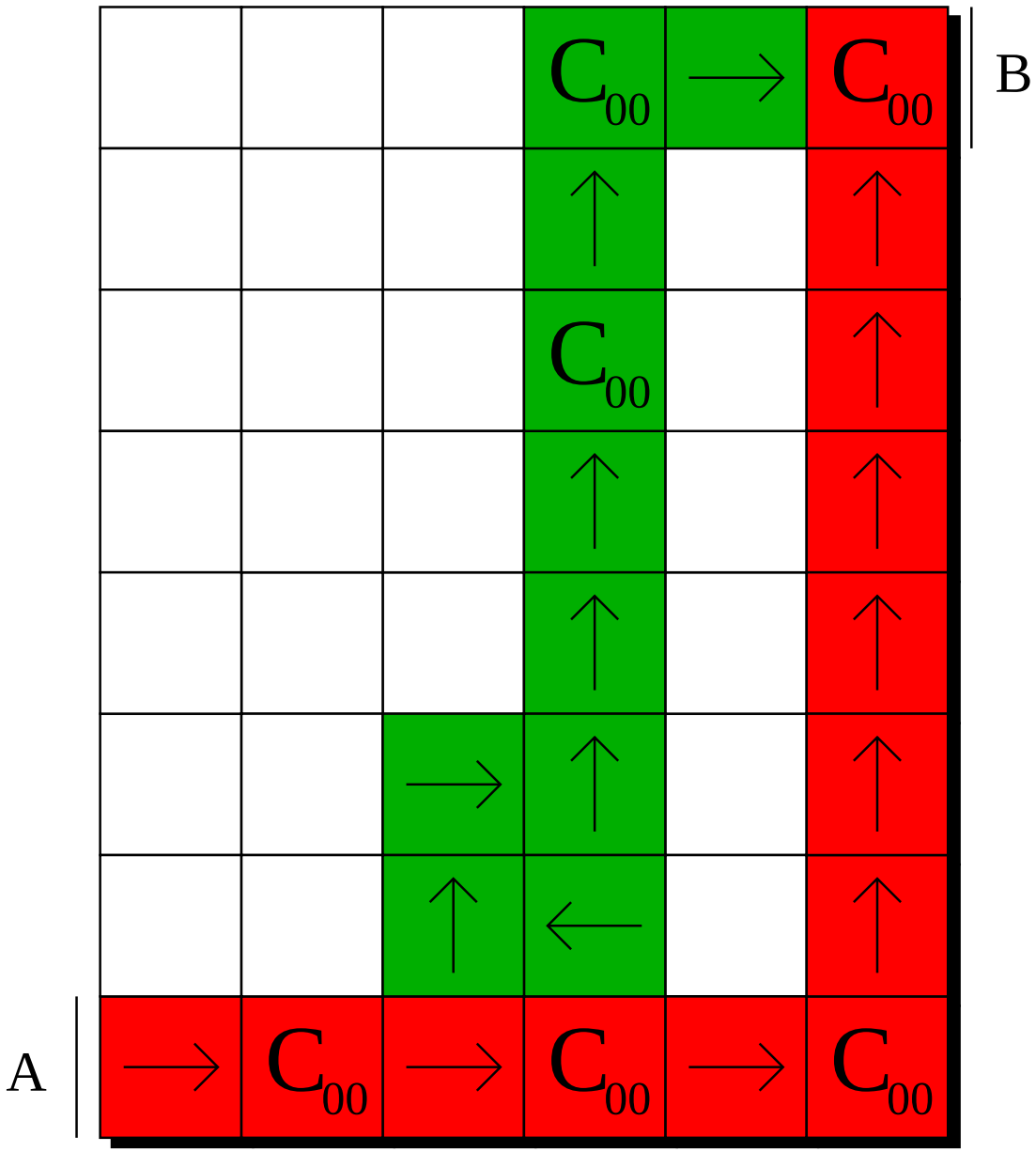
- Reconnaît une séquence de *0* et de *1*
  - k = nombre de *1*
  - n = taille de la séquence
- Taille du décodeur
  - Largeur : $2 \cdot k$ cellules
  - Hauteur : $n + 2$ cellules



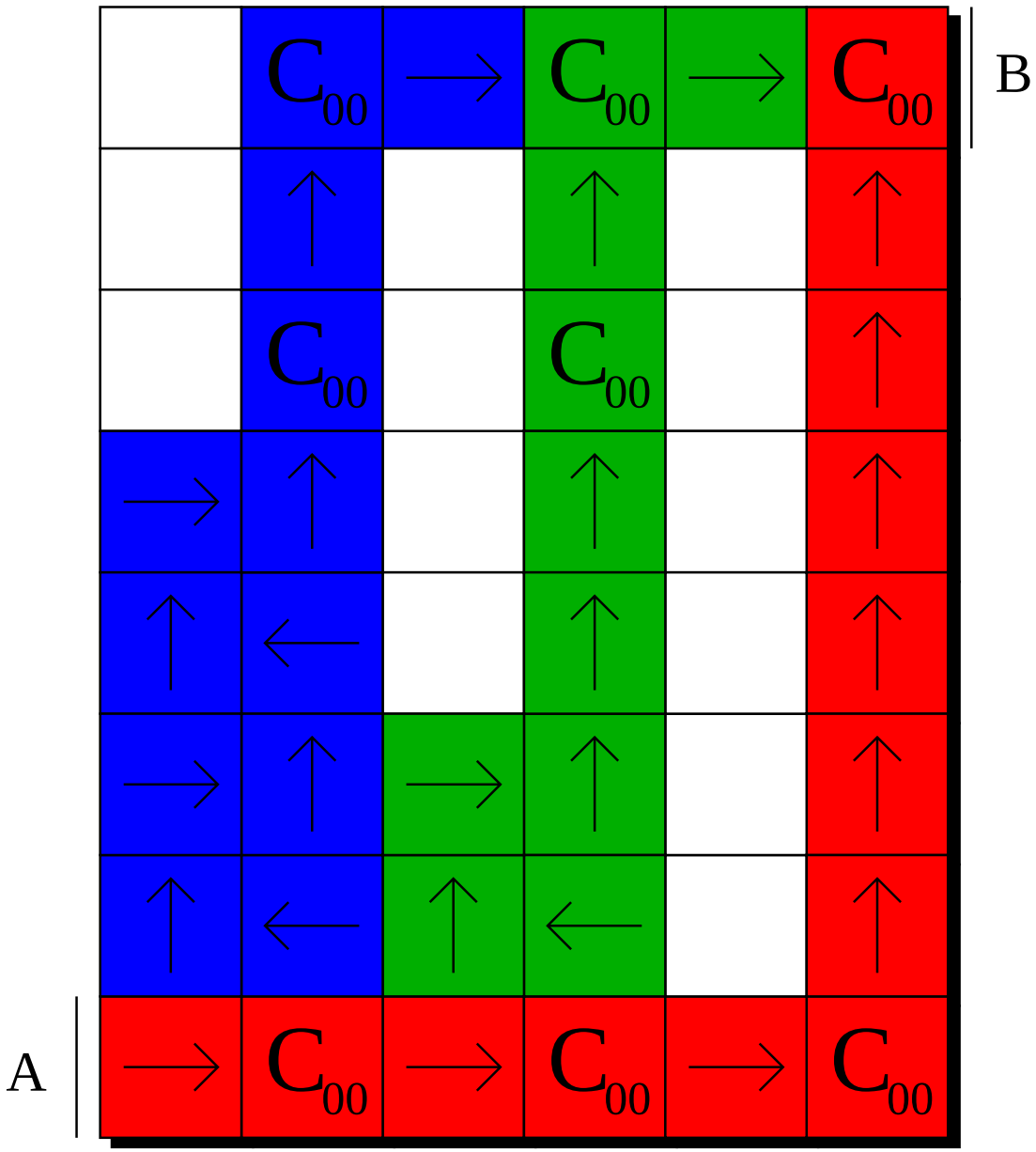
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



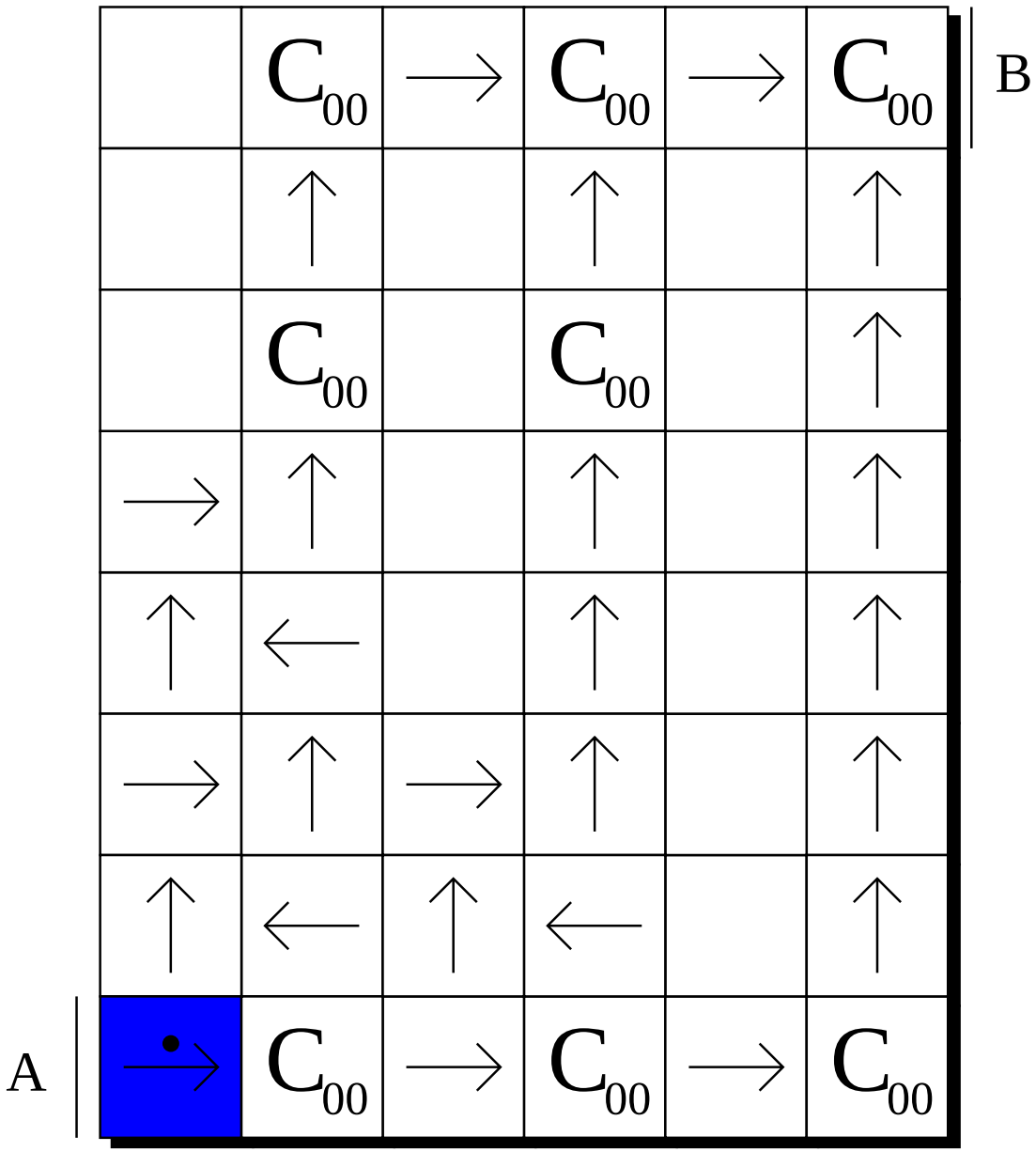
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



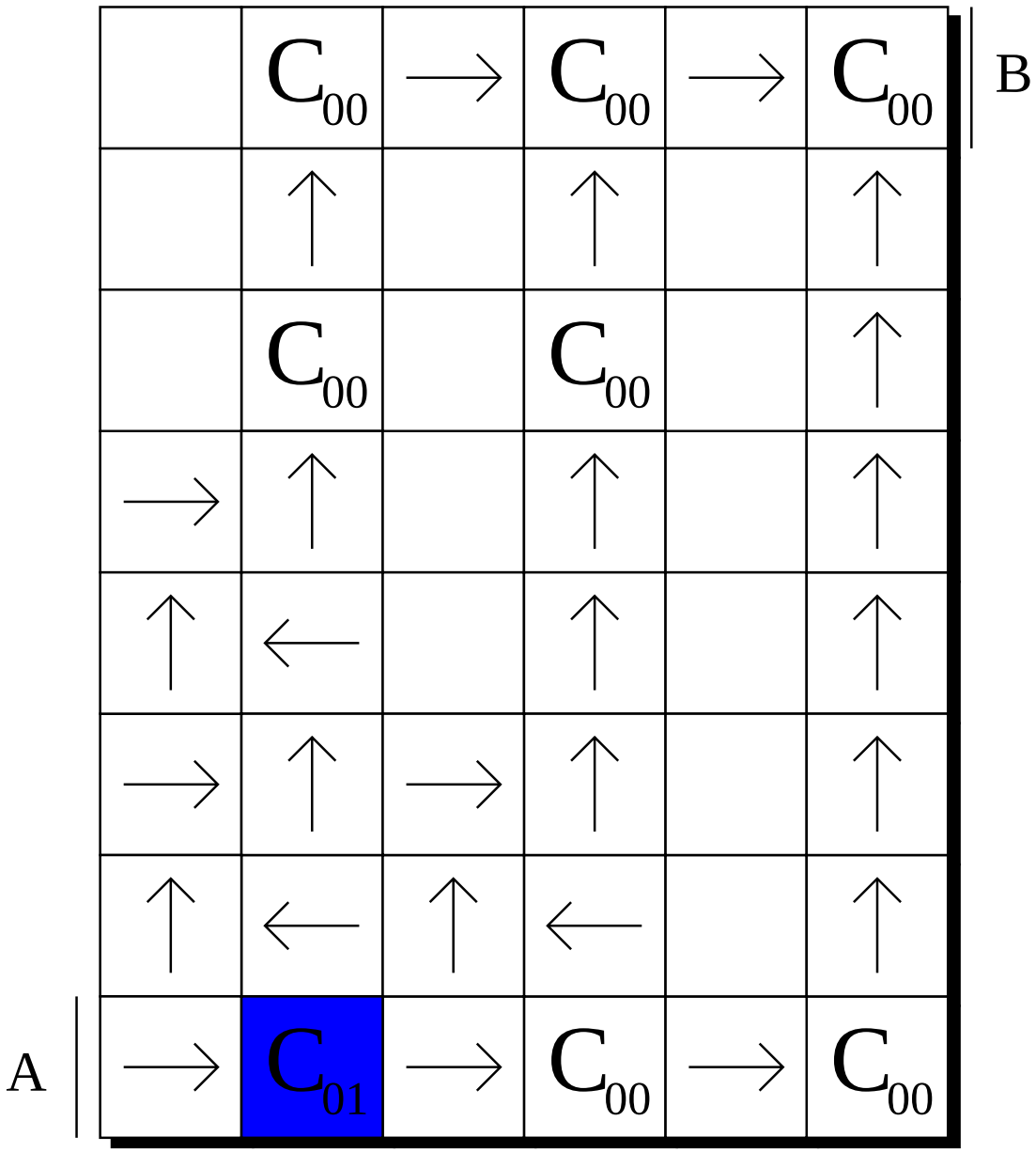
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



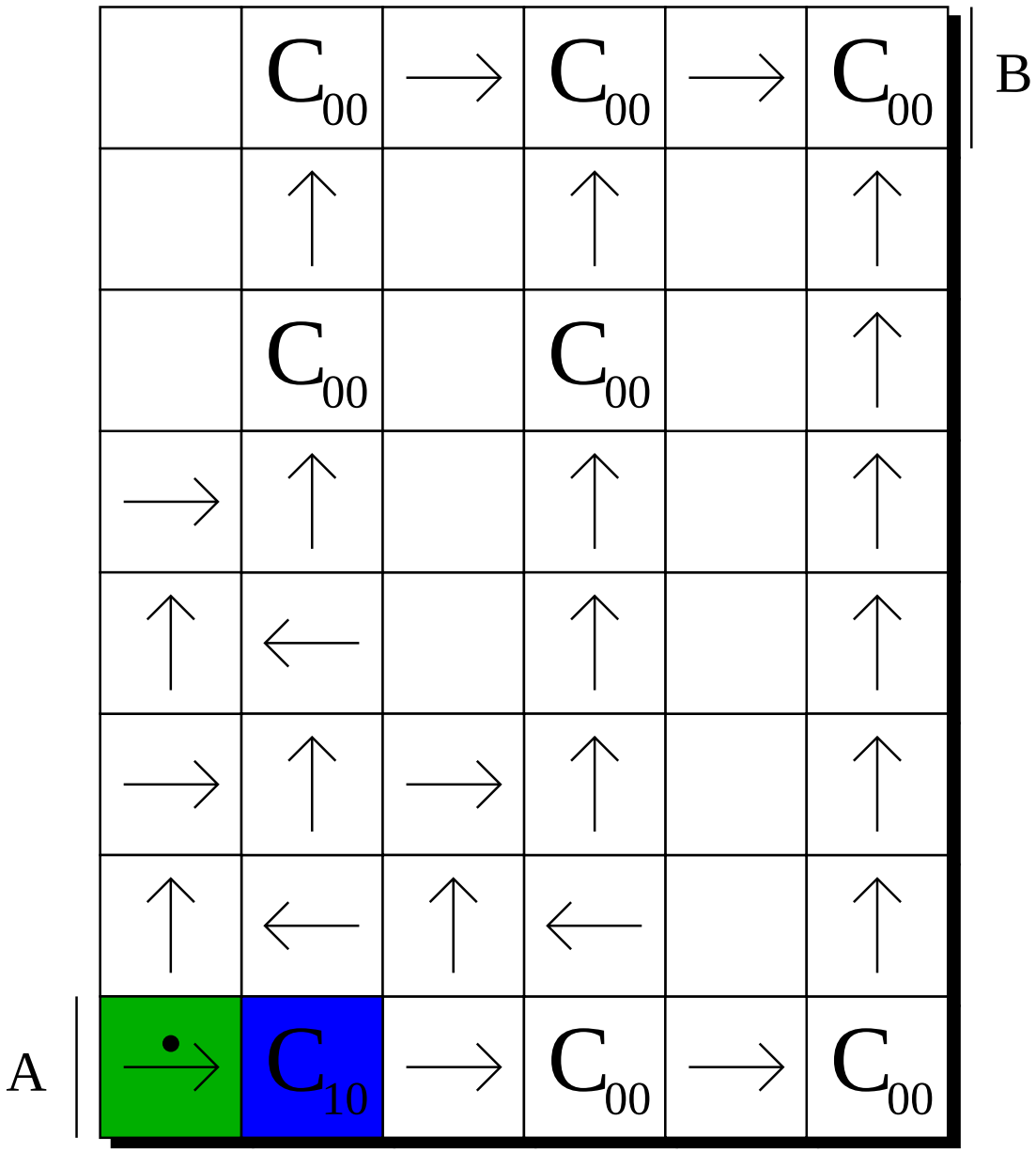
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



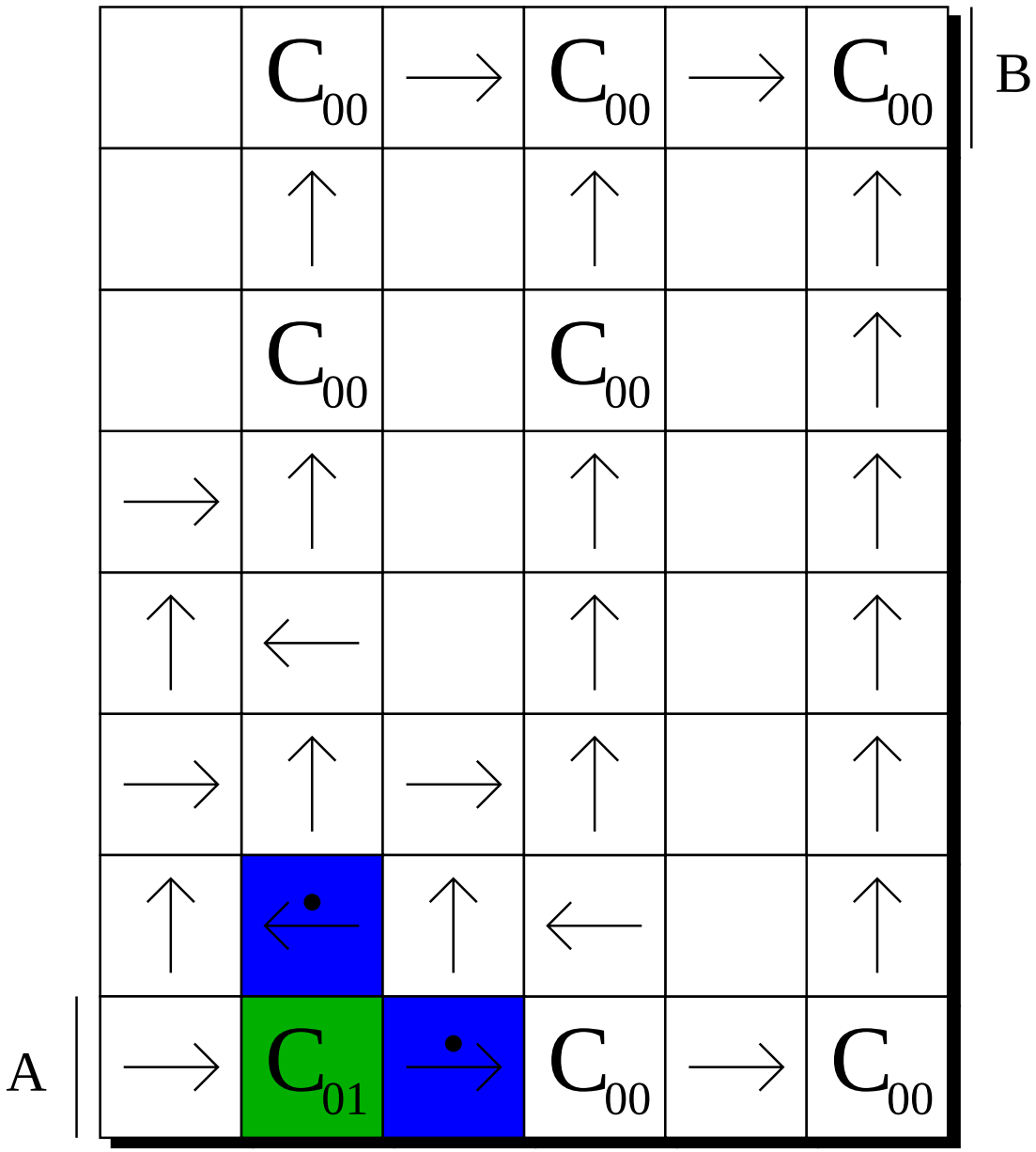
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



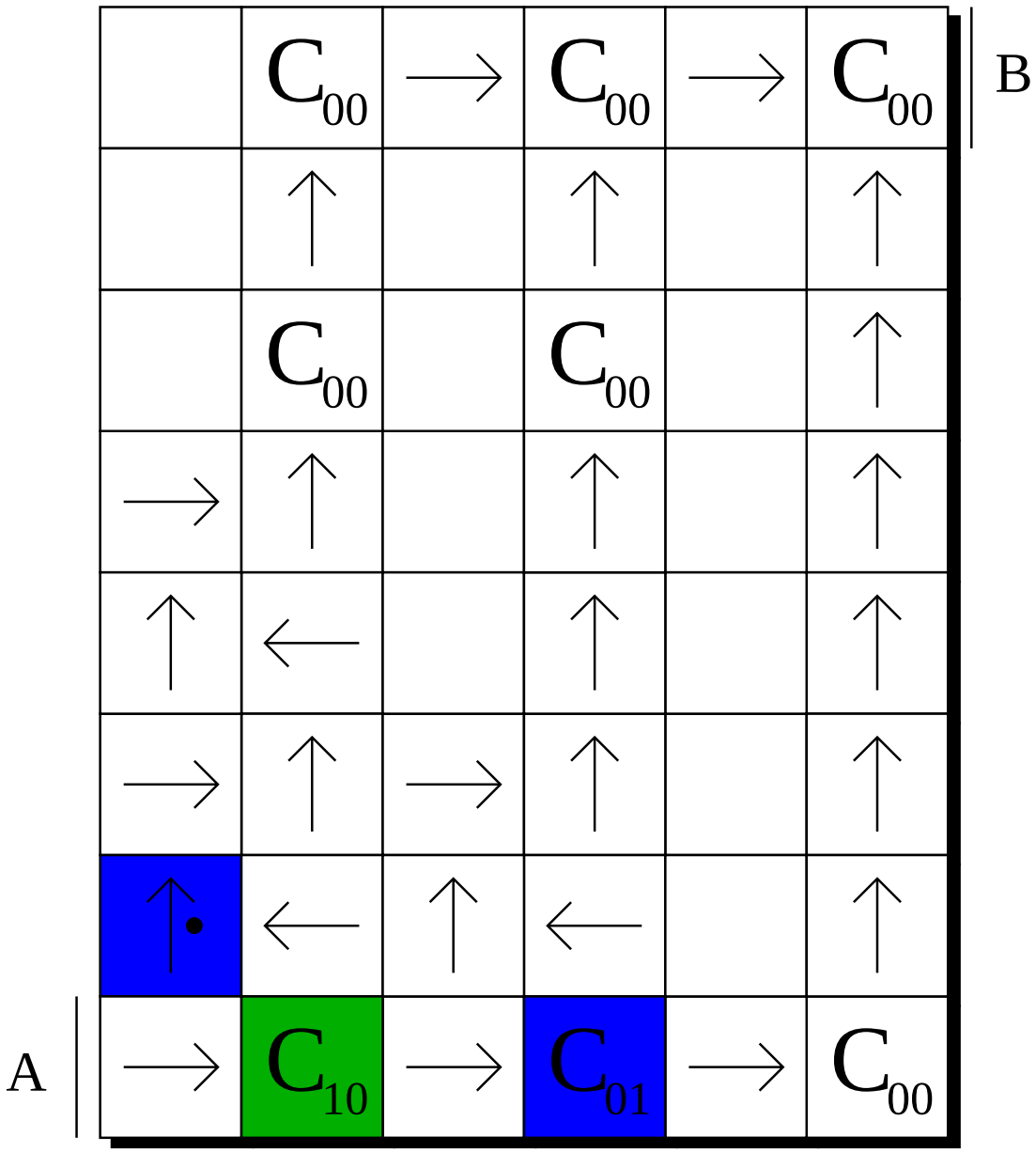
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



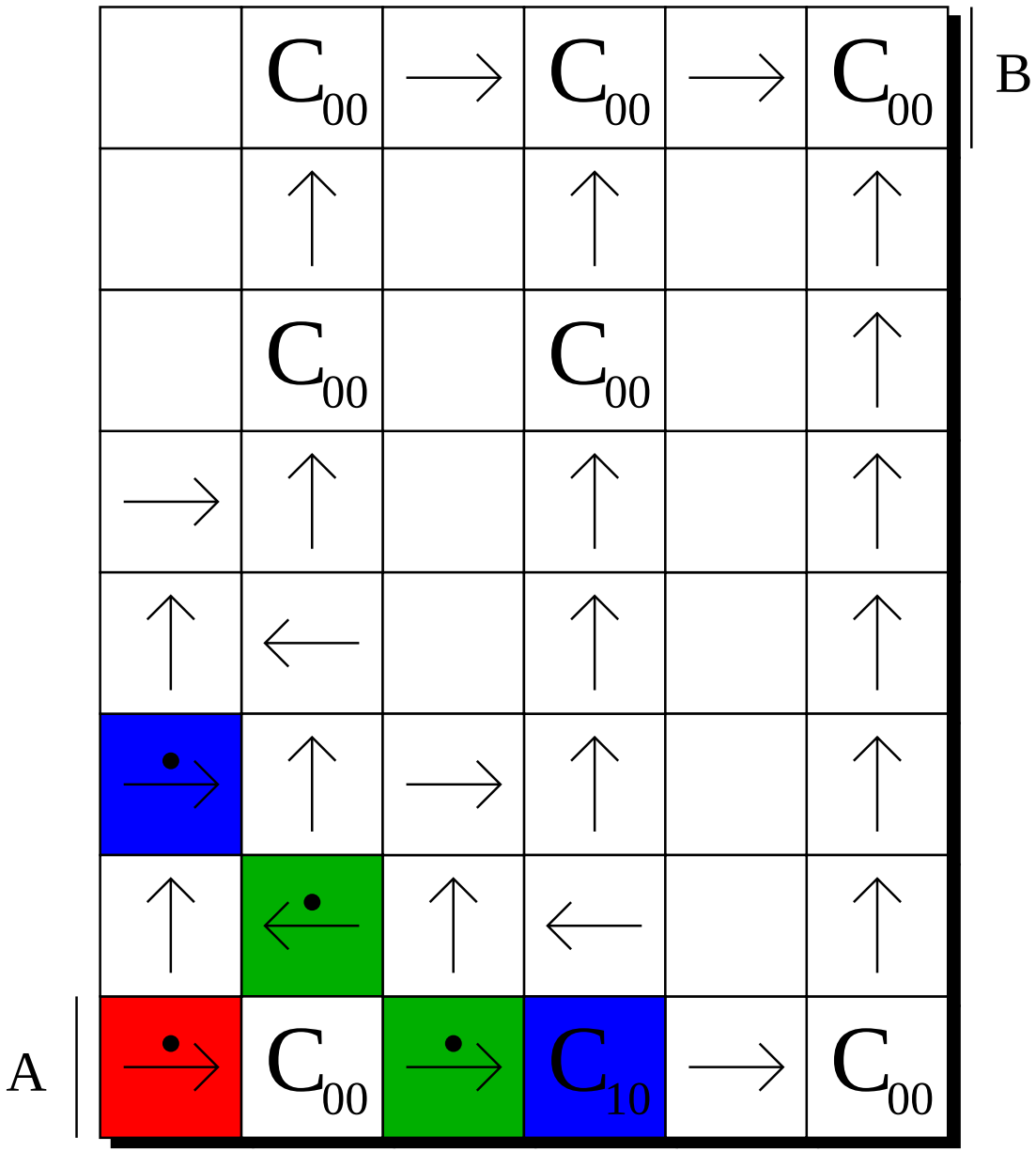
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



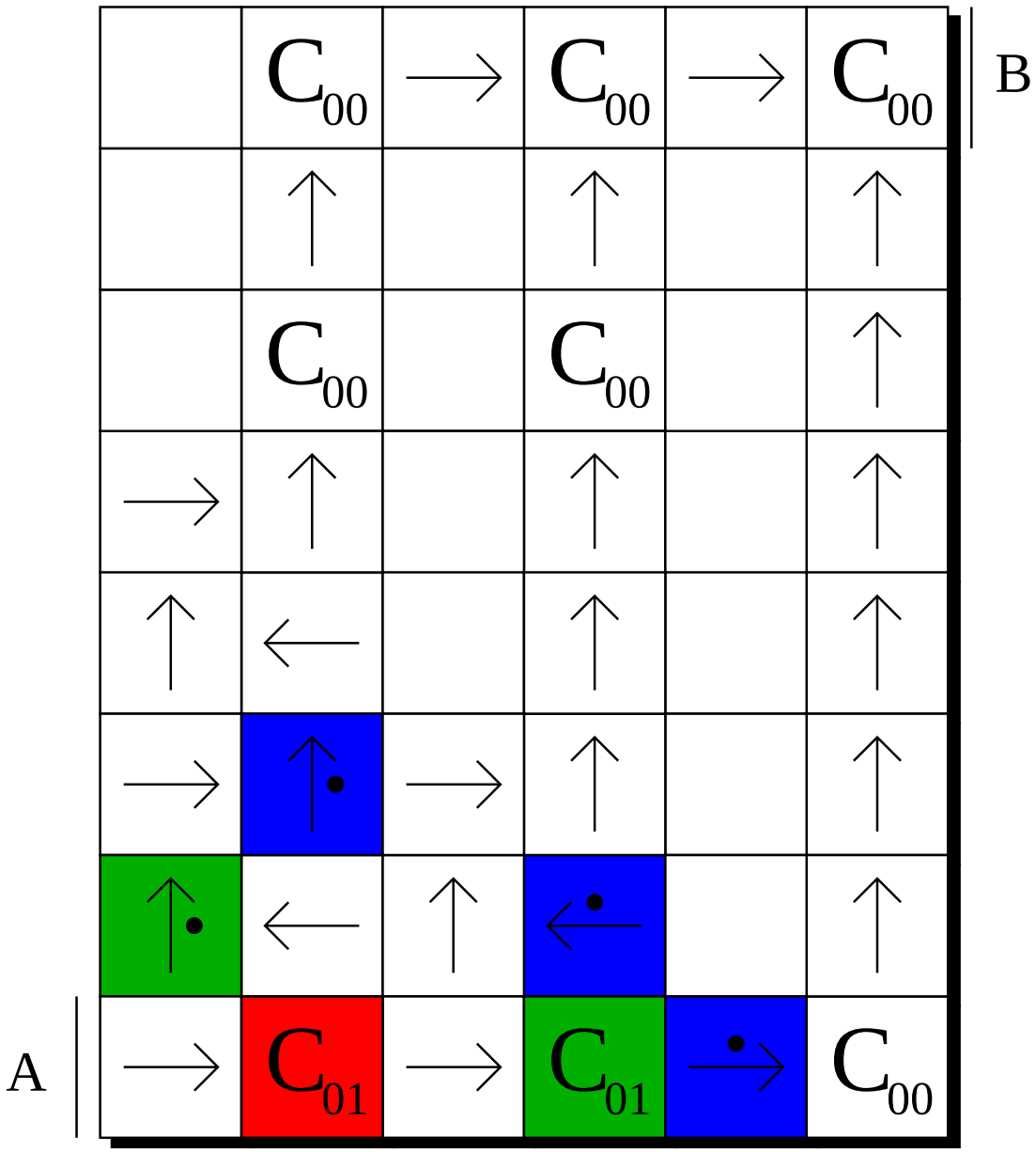
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



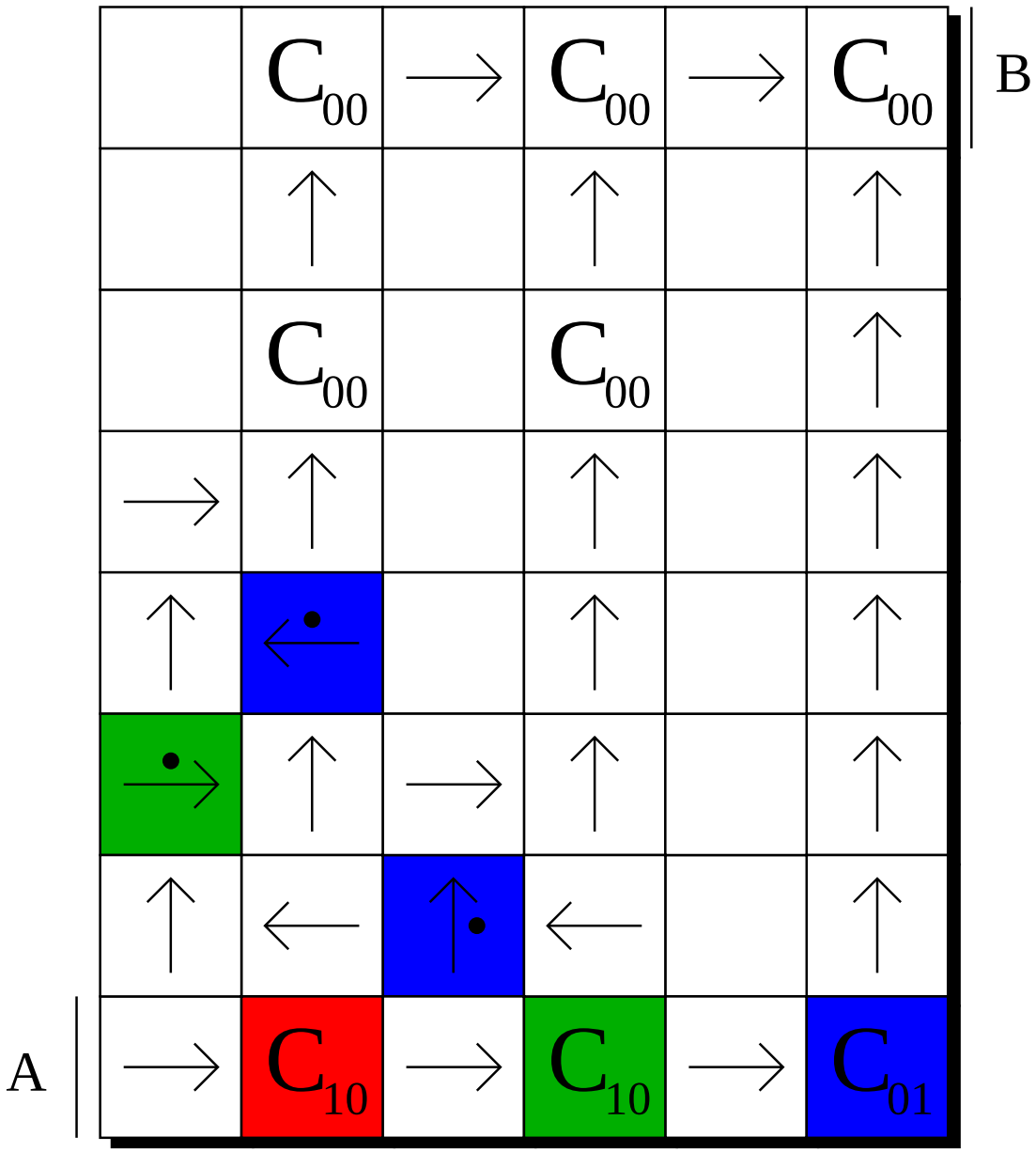
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



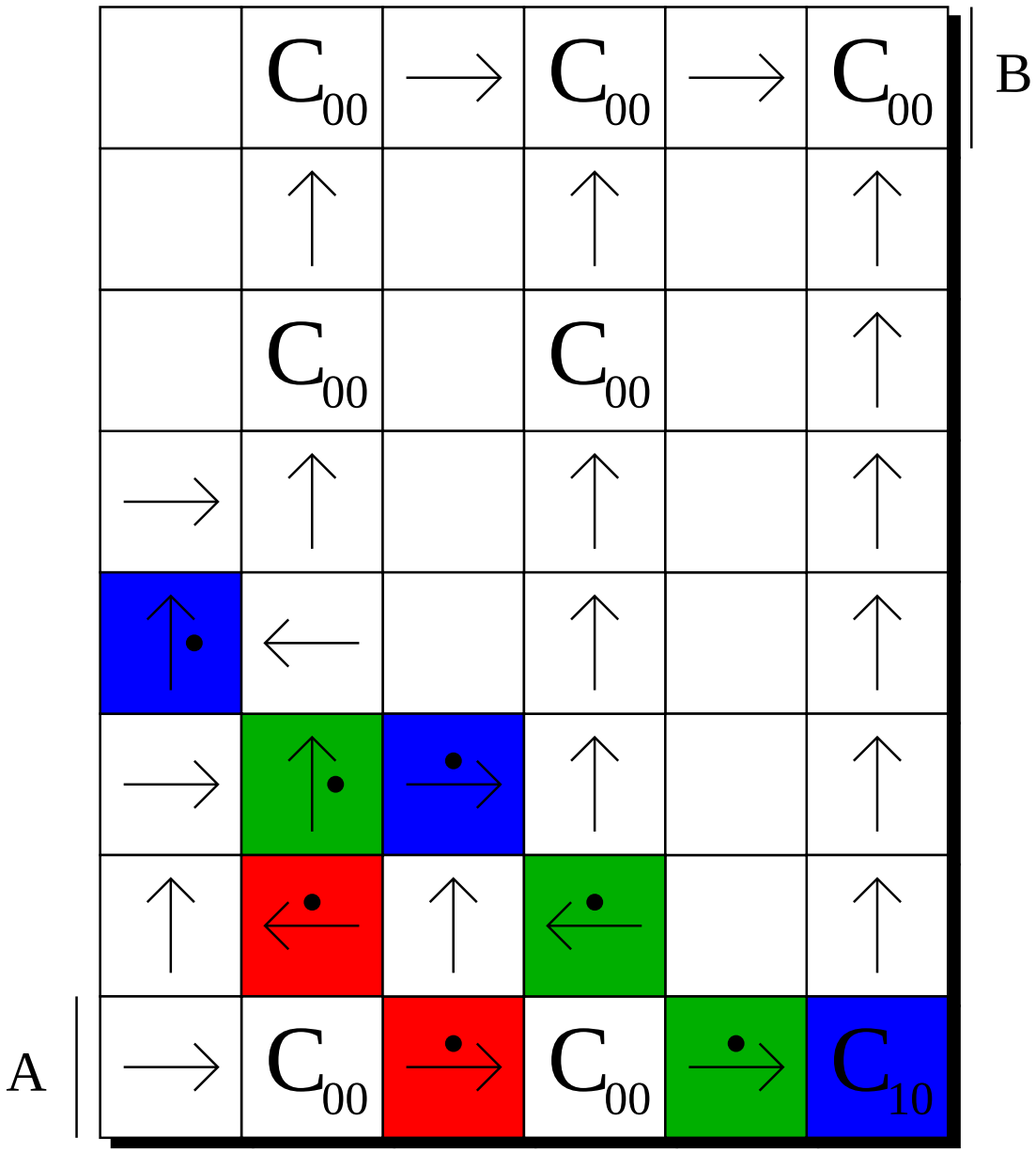
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



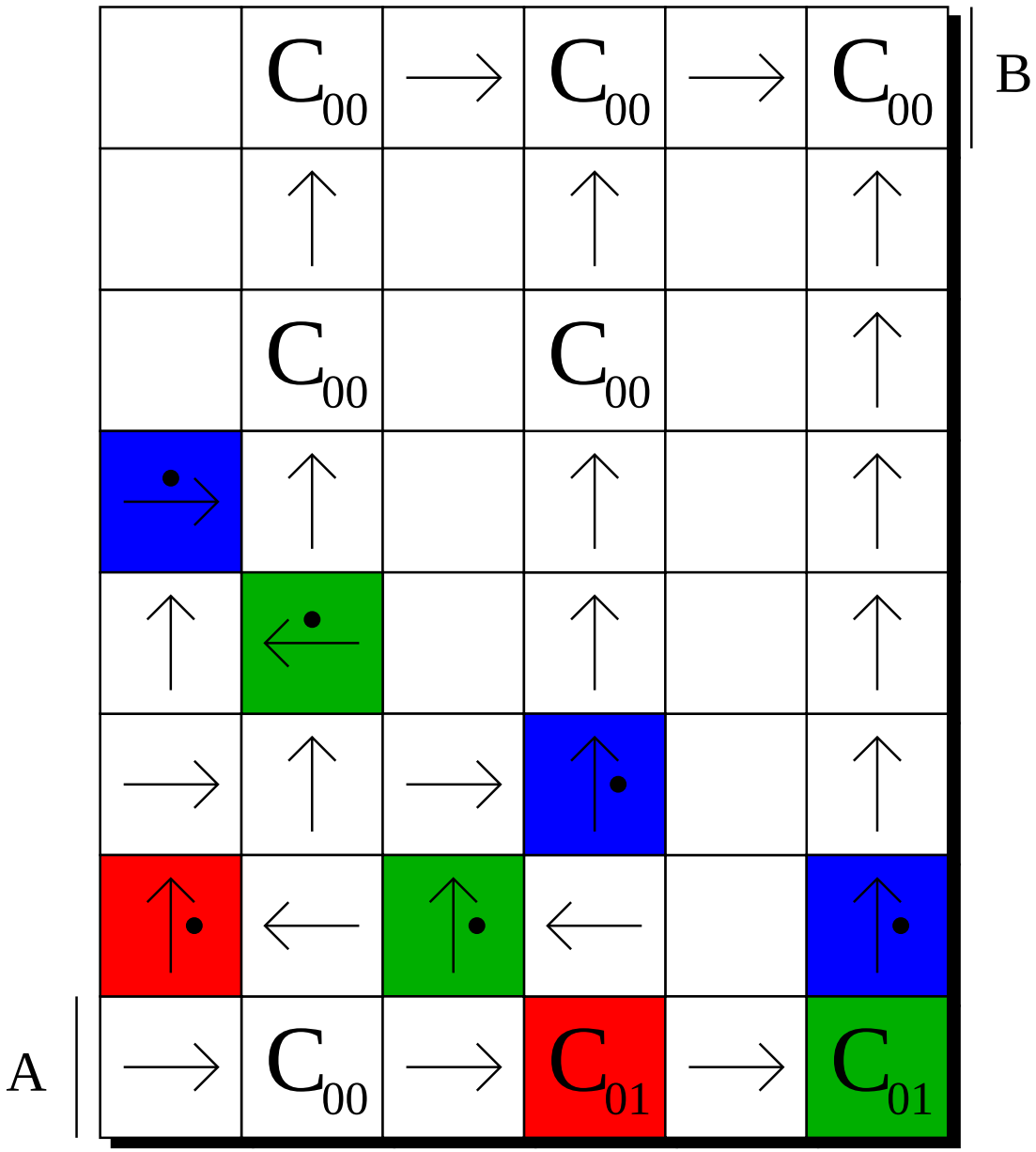
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



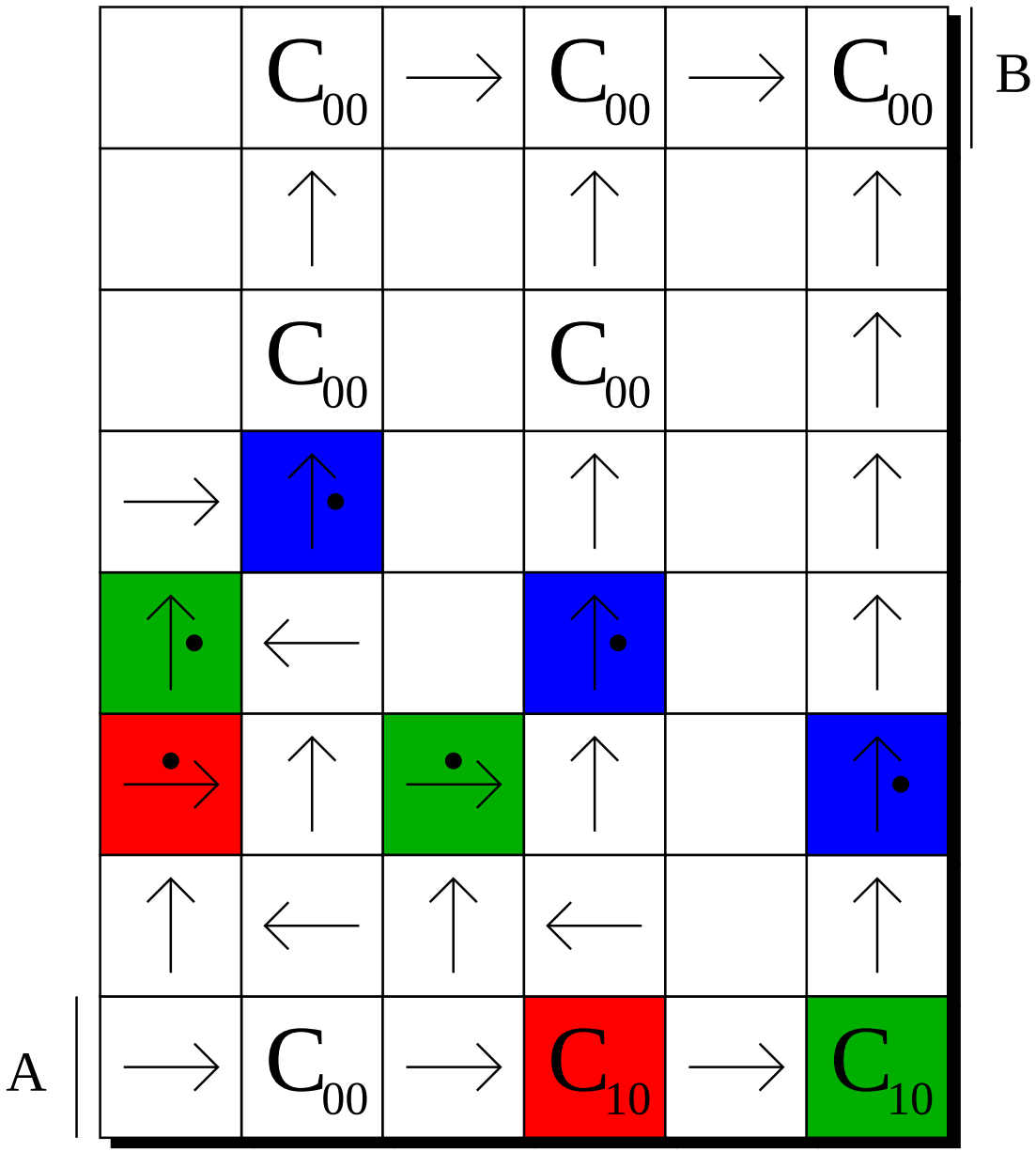
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



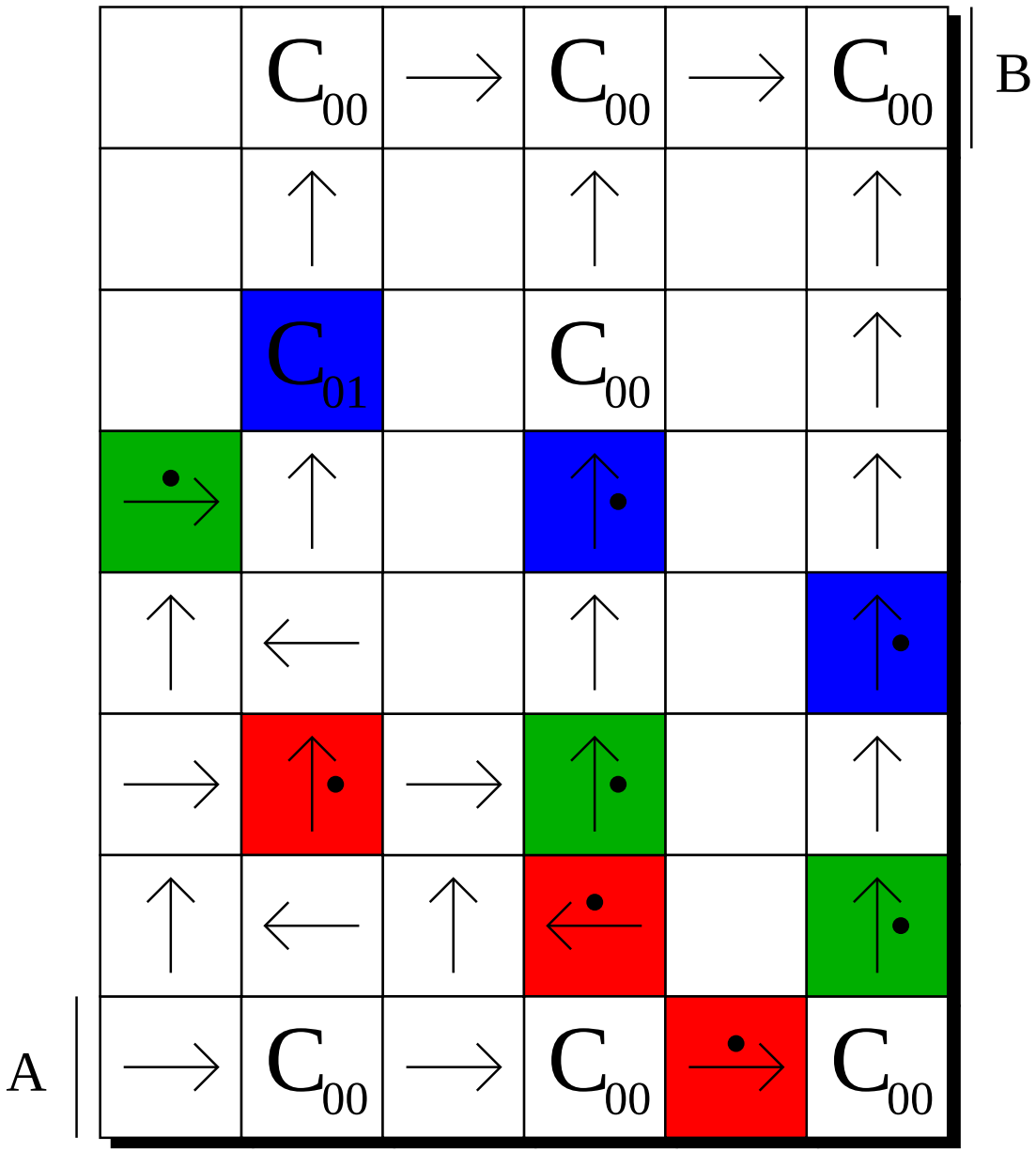
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



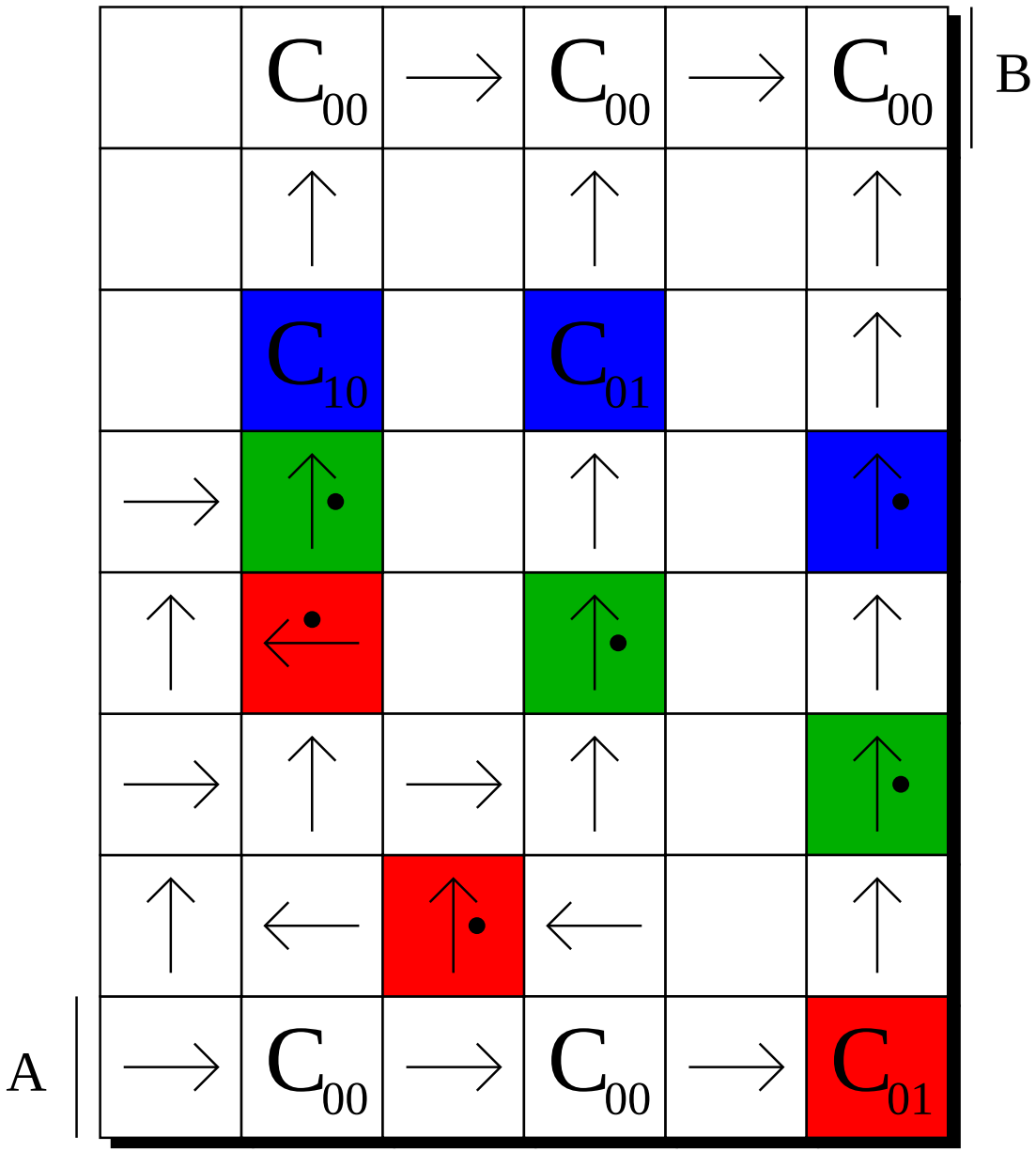
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



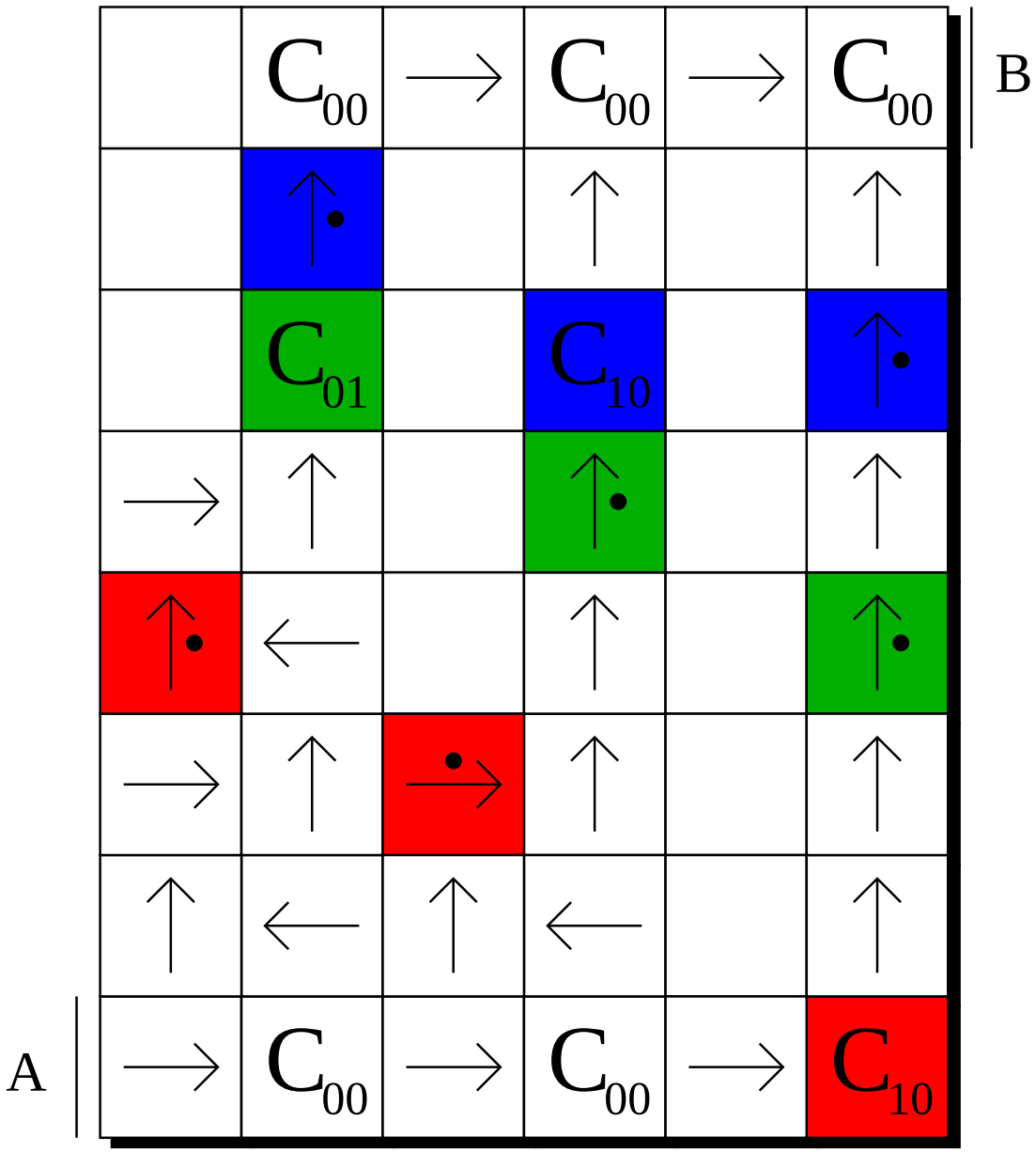
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



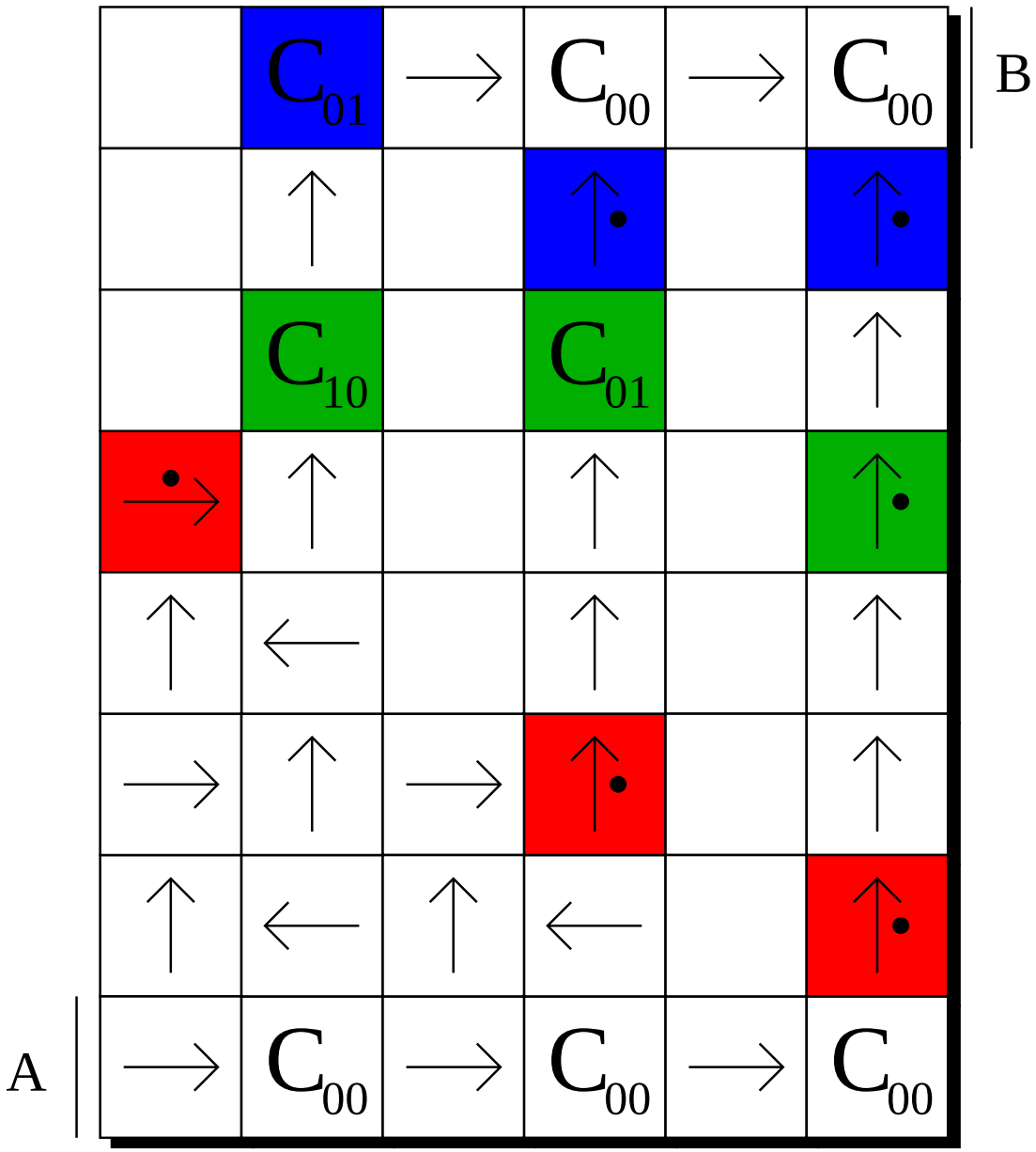
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



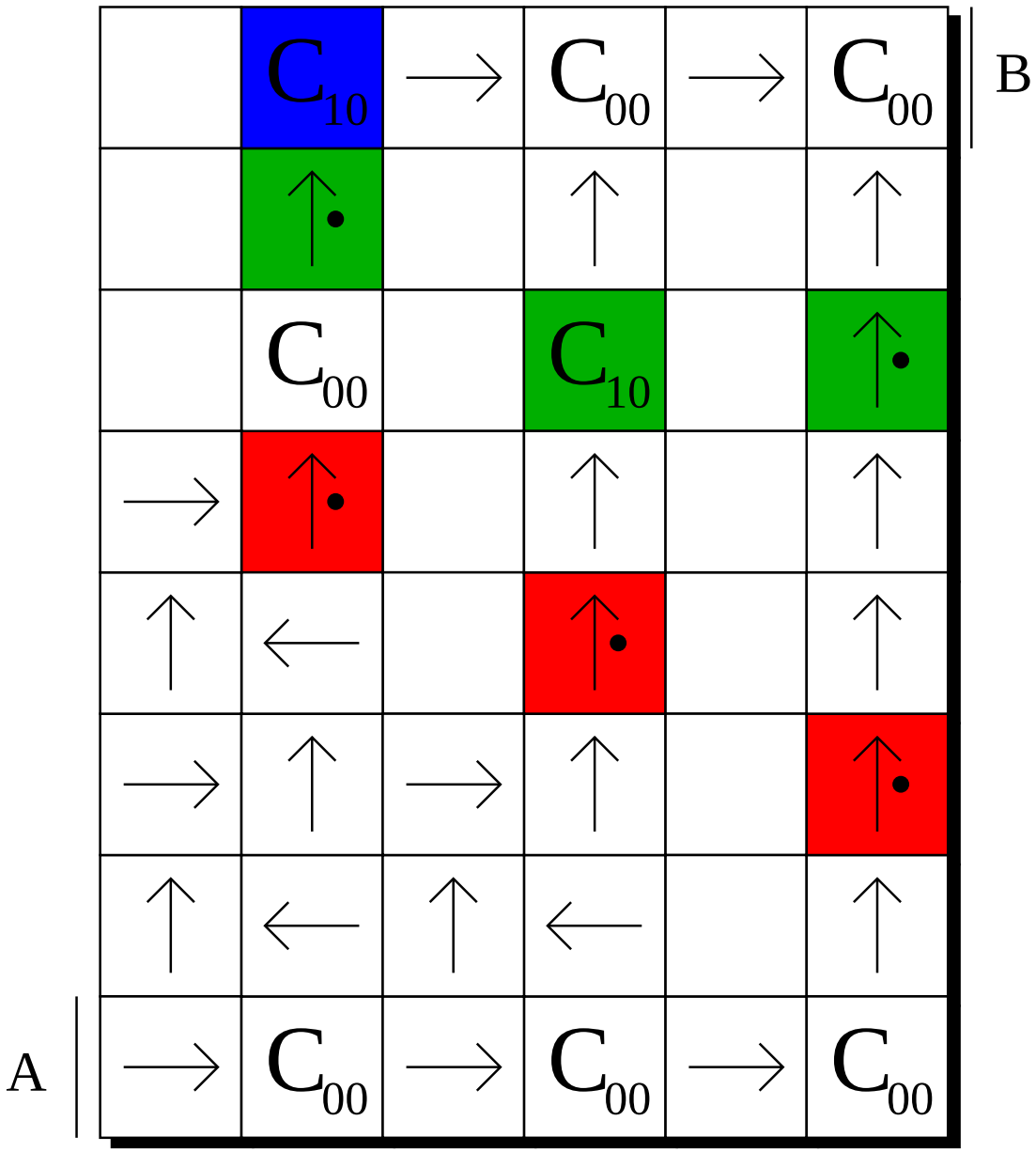
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



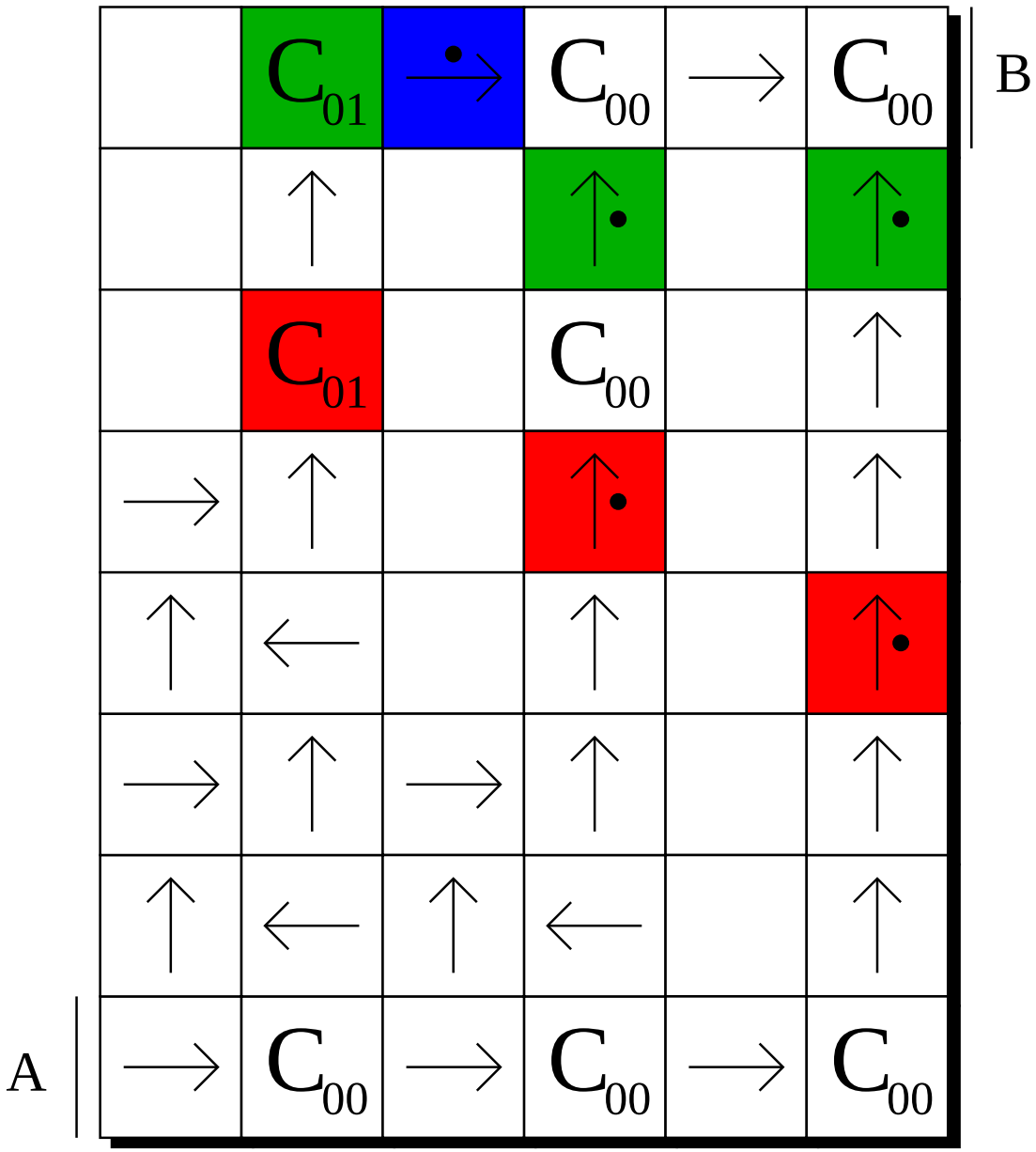
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



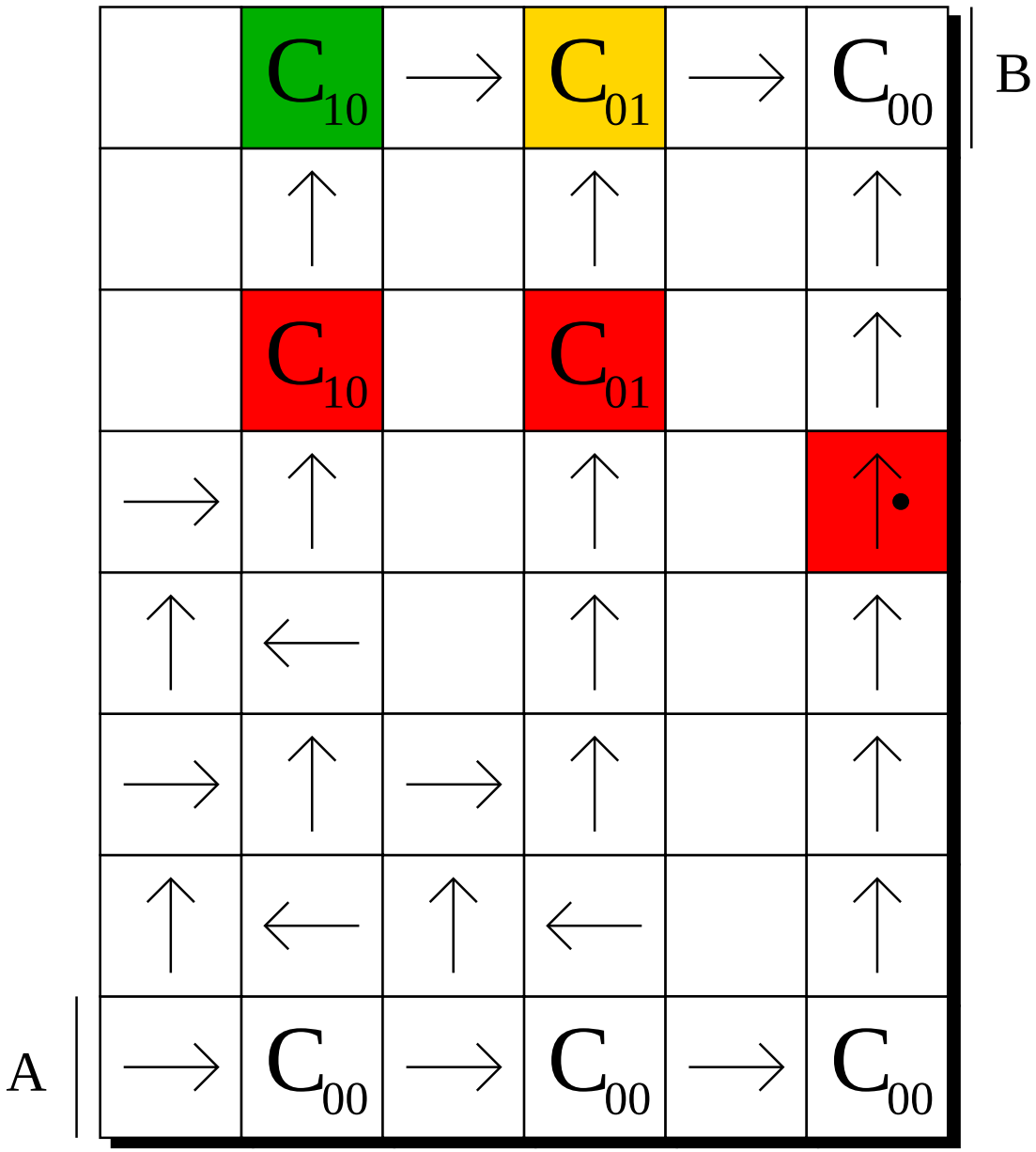
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



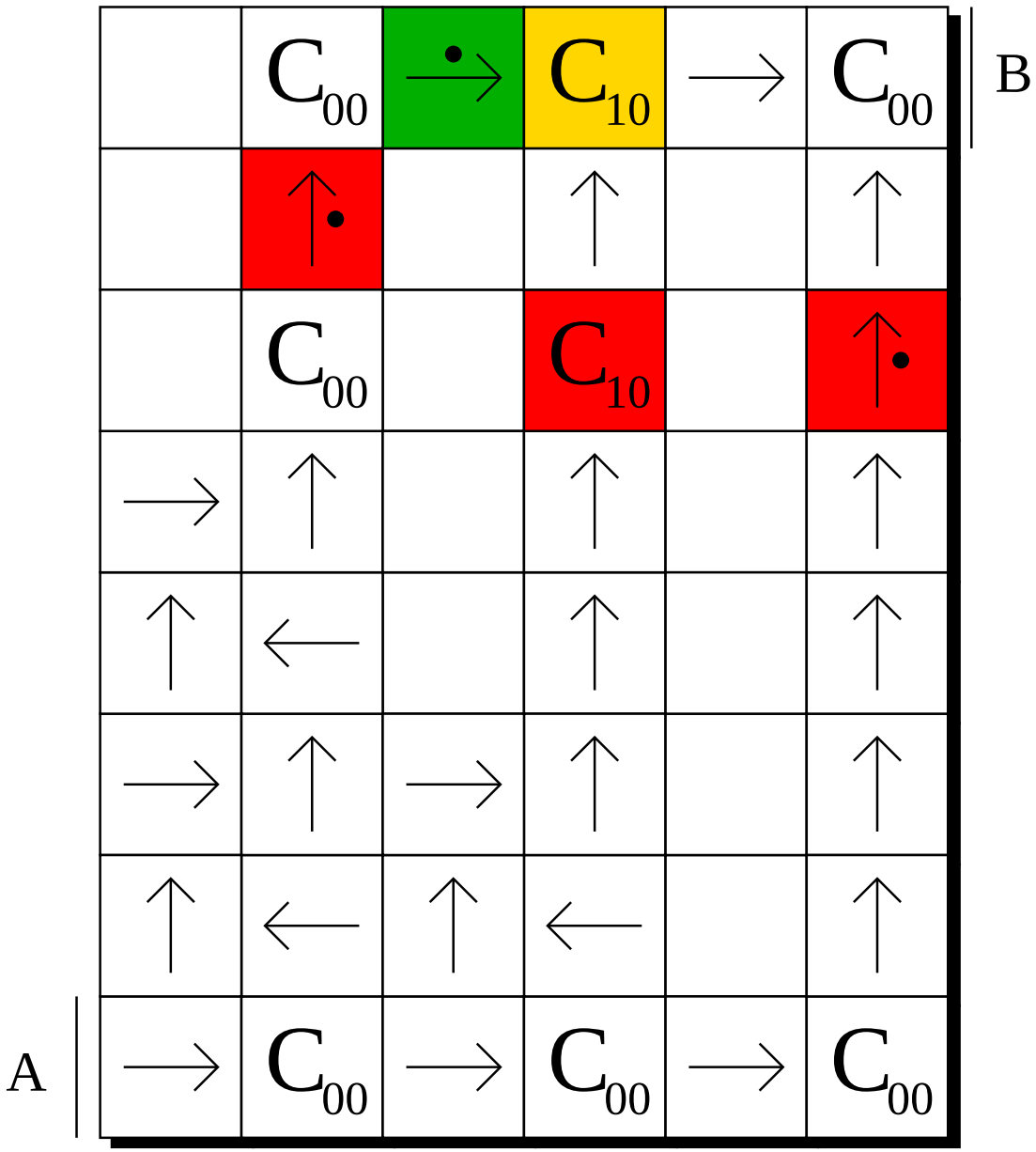
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



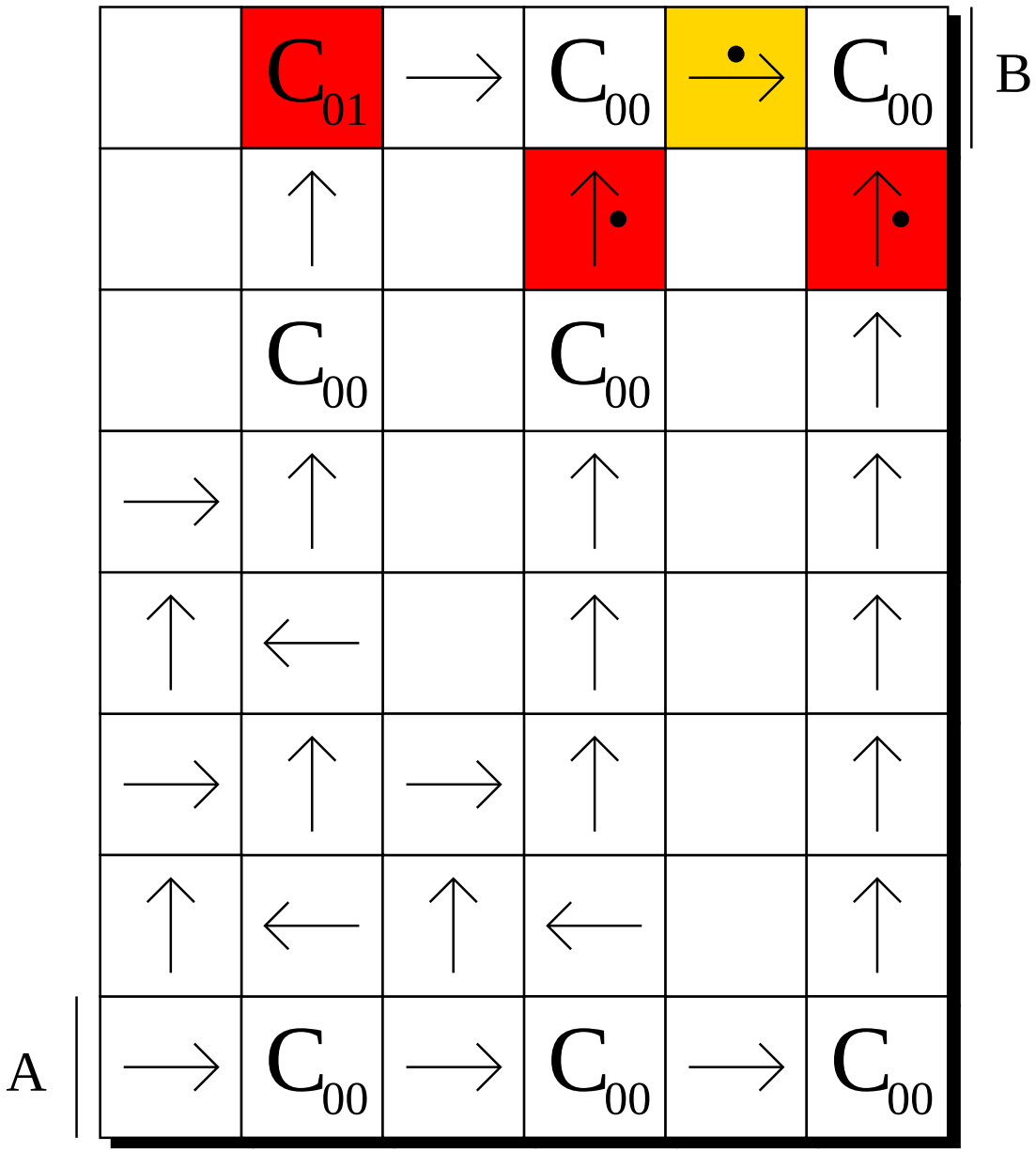
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



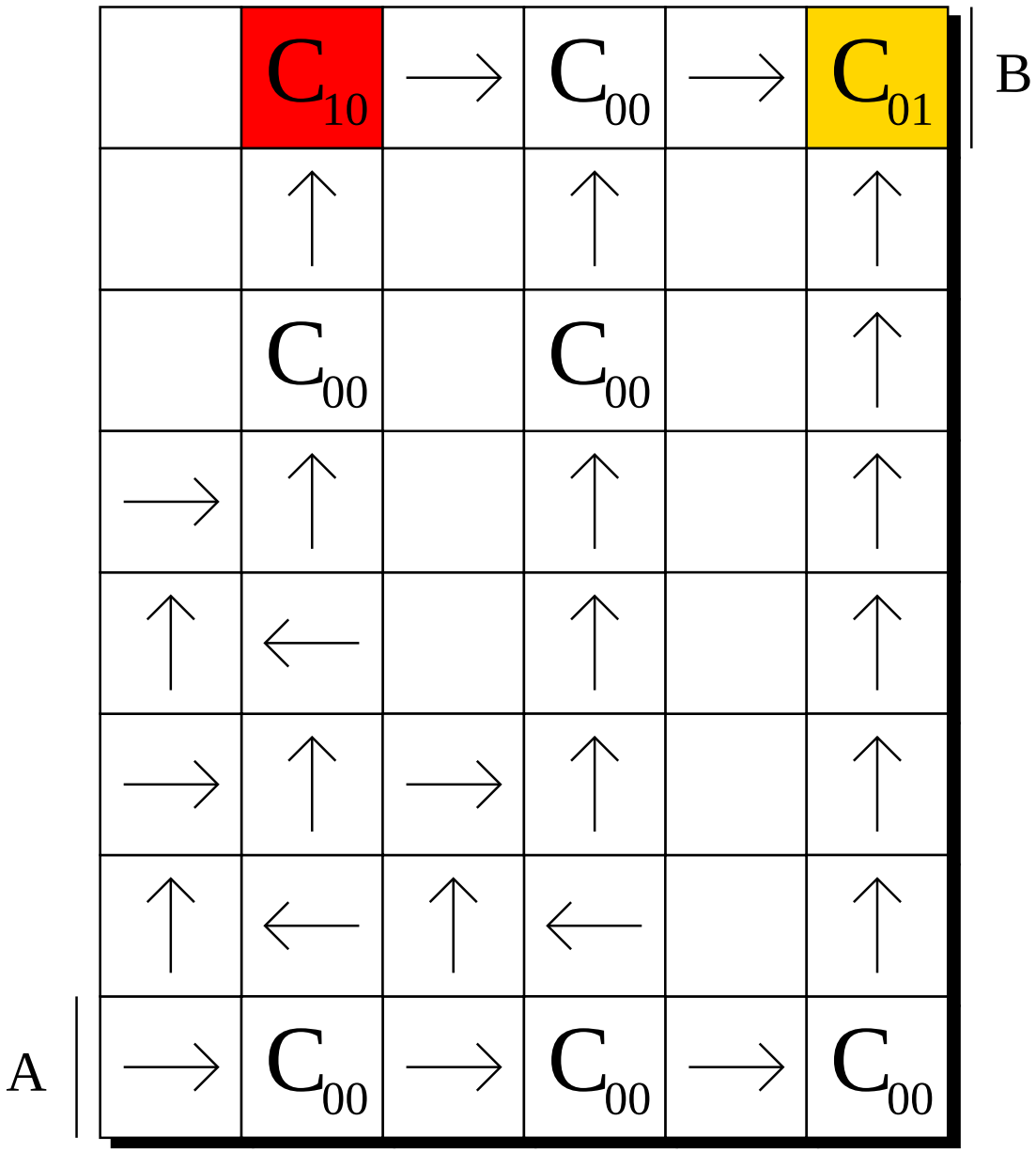
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



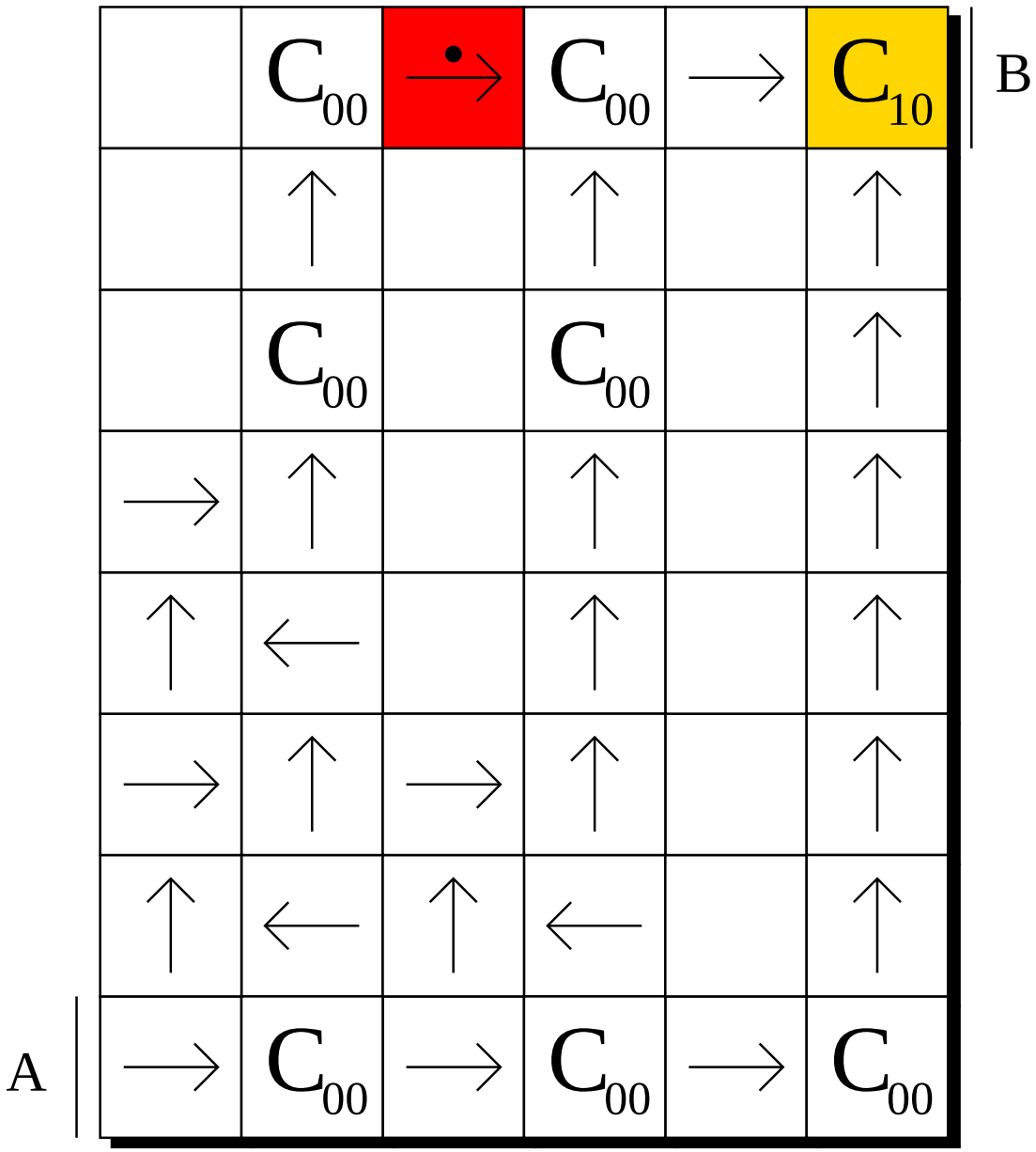
- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules



- Décodeur D(1 0 1 0 0 1)
  - $k = 3 \Rightarrow$ Largeur $= 2 \cdot k =$ 6 cellules
  - $n = 6 \Rightarrow$ Hauteur $= n + 2 =$ 8 cellules

- Remarque

D(101001) décode toute séquence 1 ϕ 1 ϕ ϕ 1

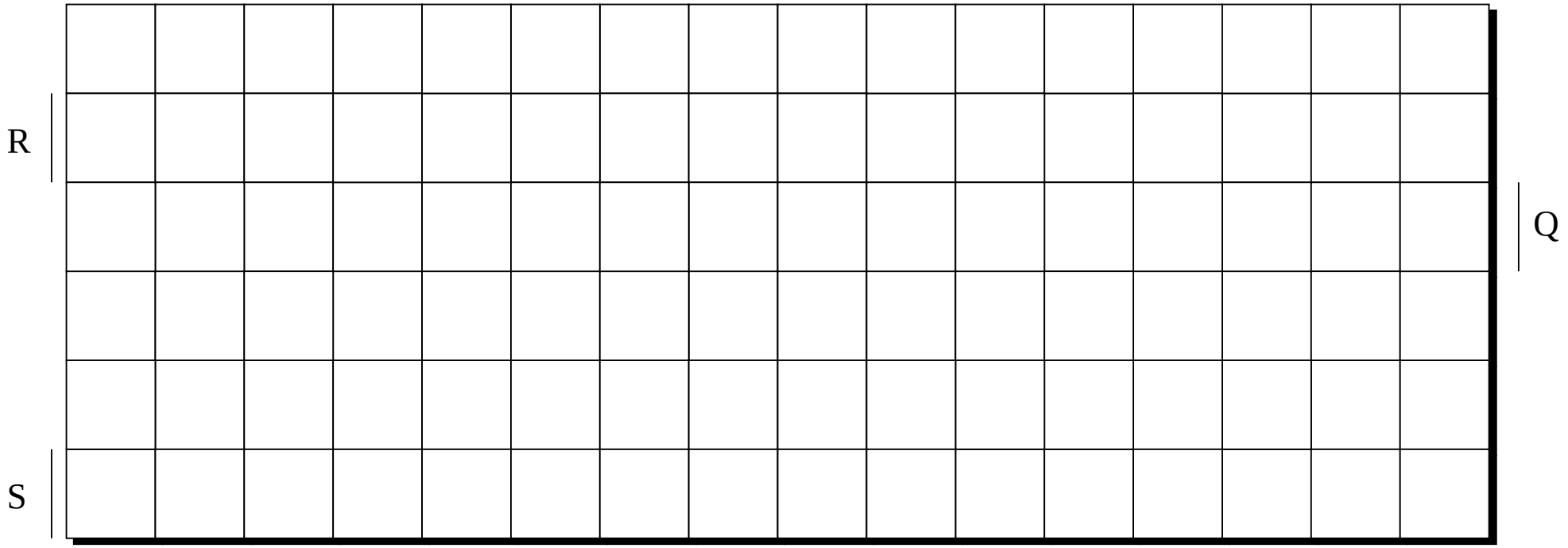
- Exemples

⇒ 1 0 1 0 1 1

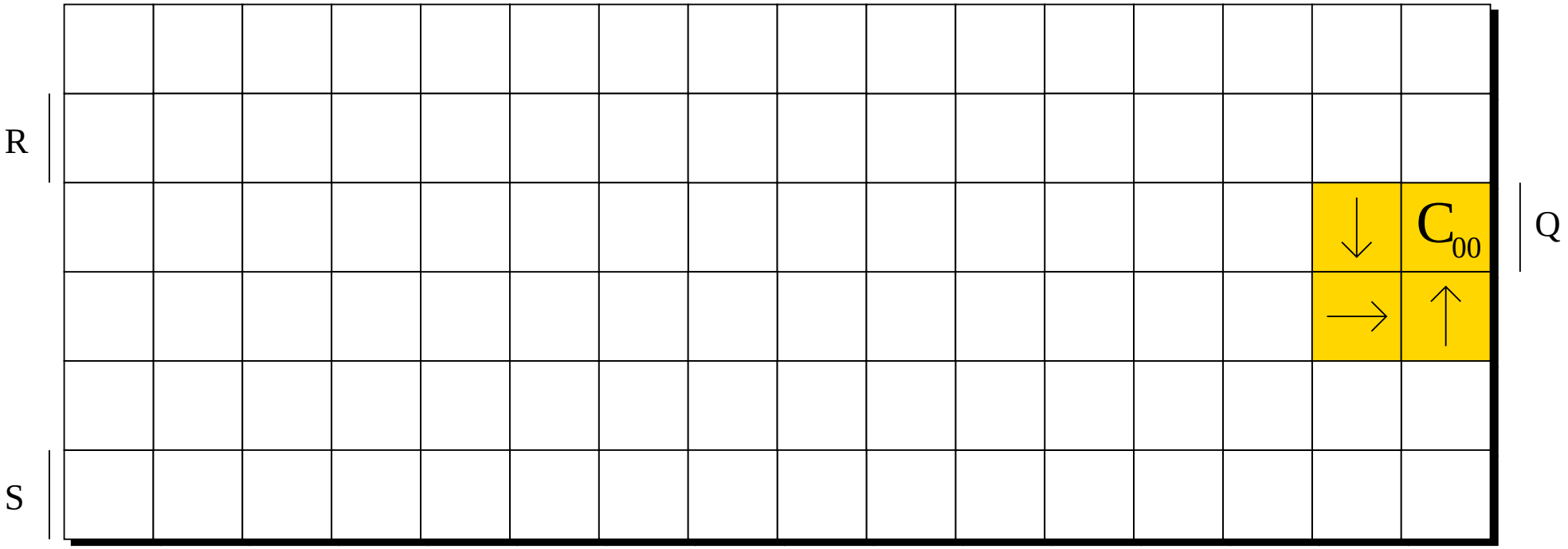
⇒ 1 0 1 1 1 1

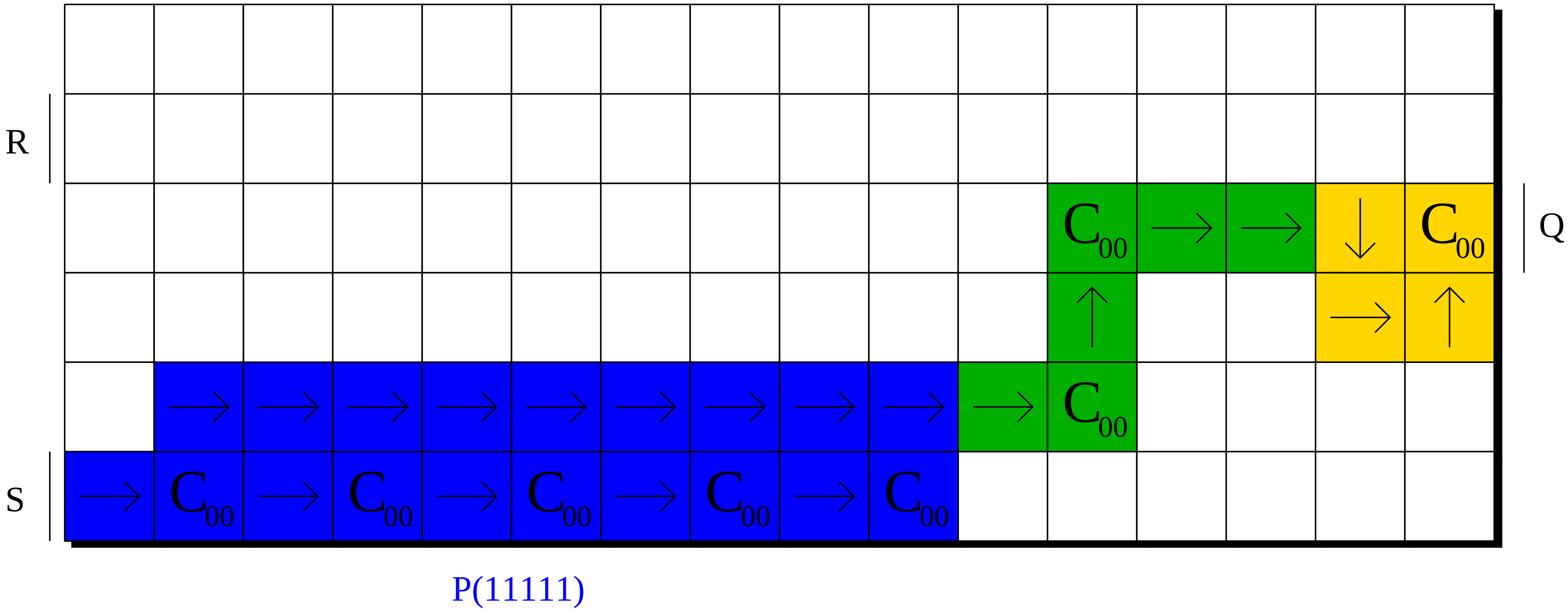
⇒ . . .

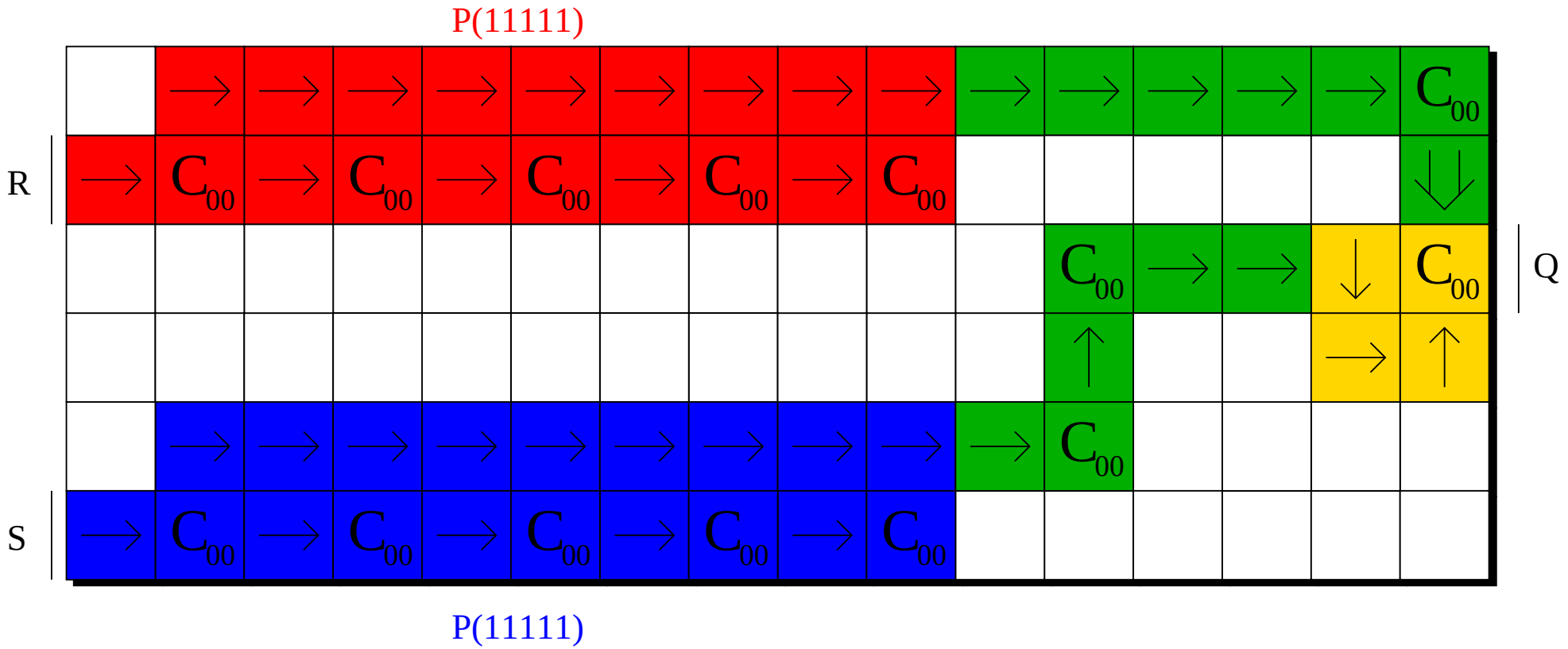
Application : la bascule SR



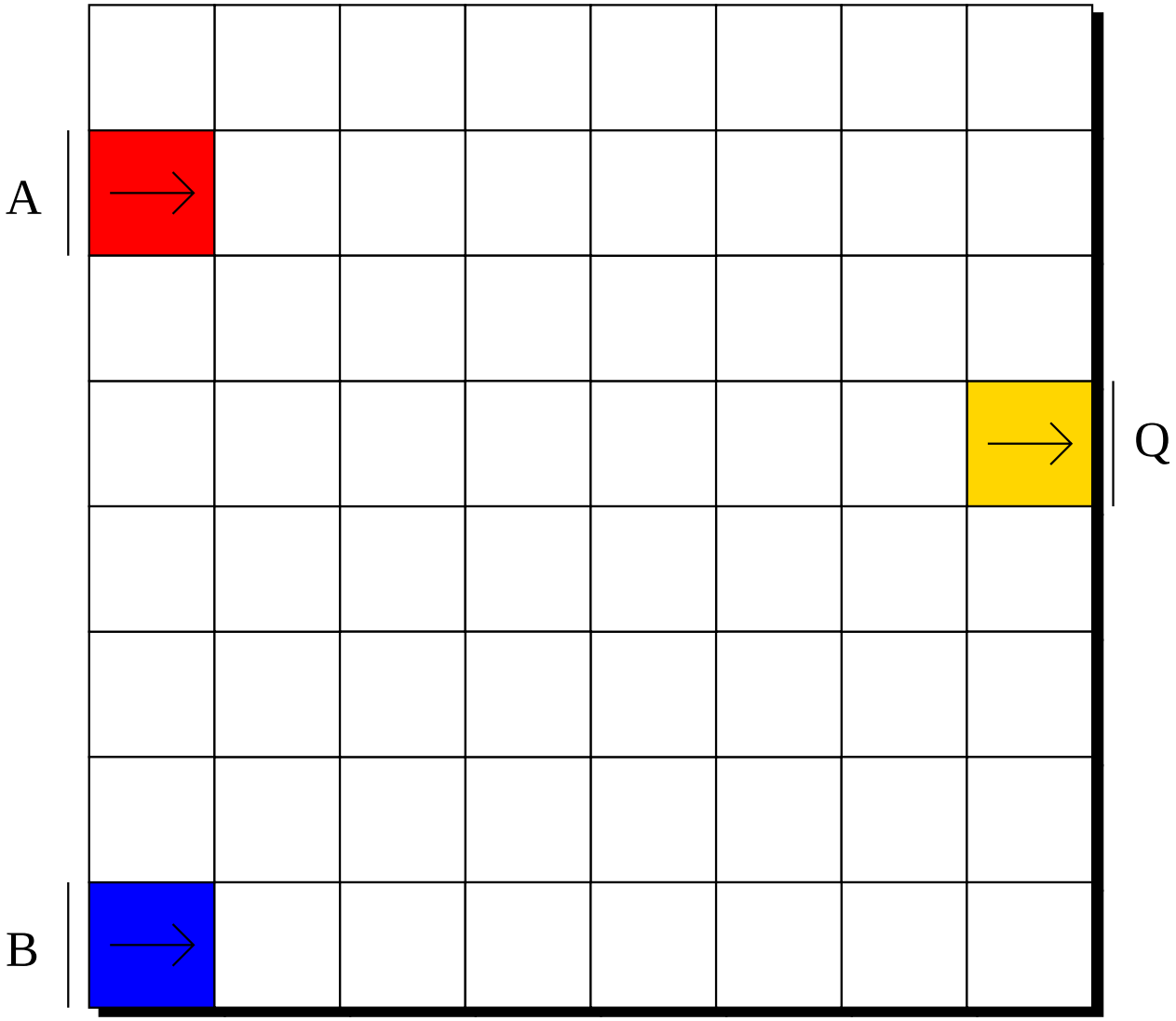
Application : la bascule SR

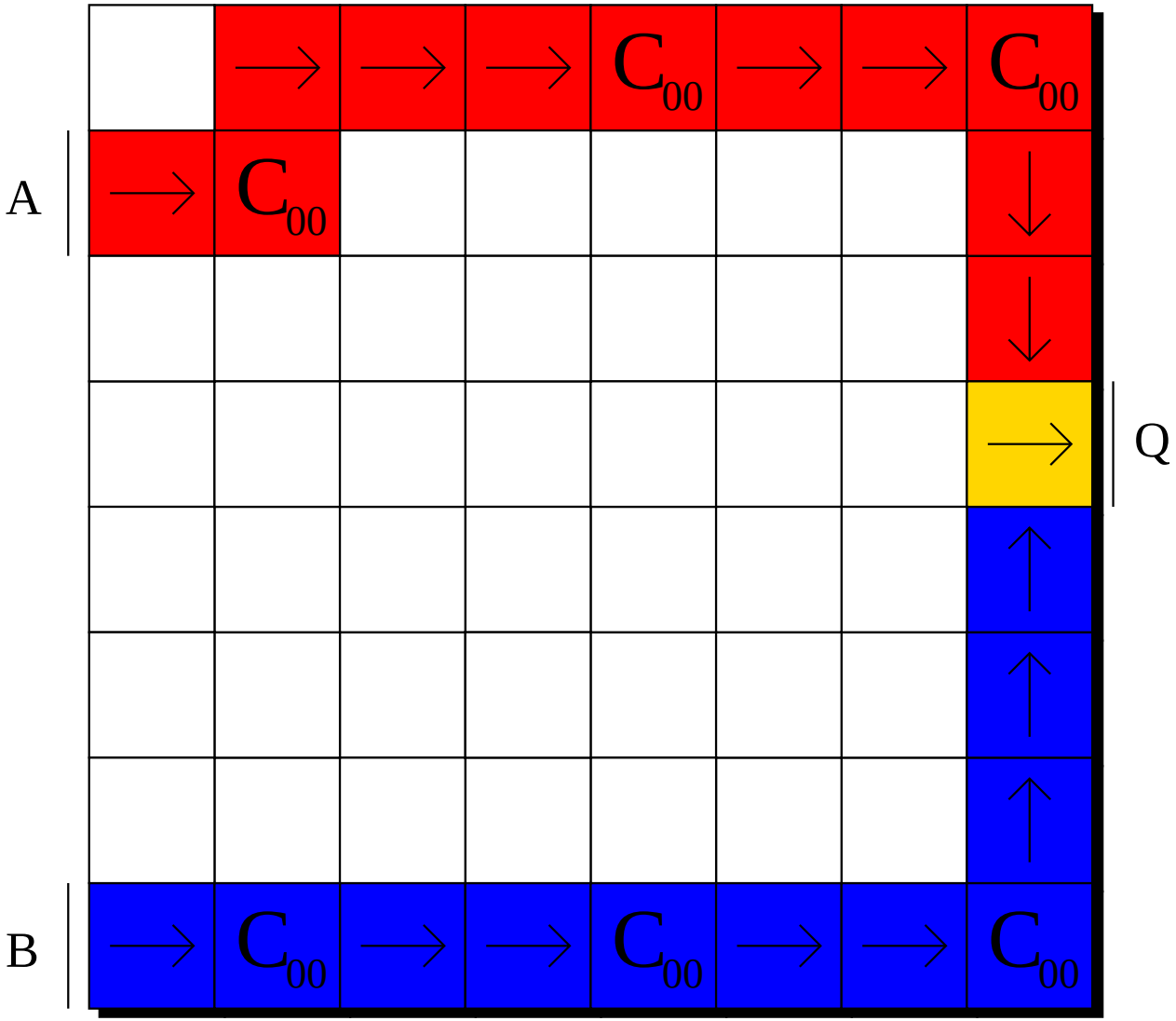


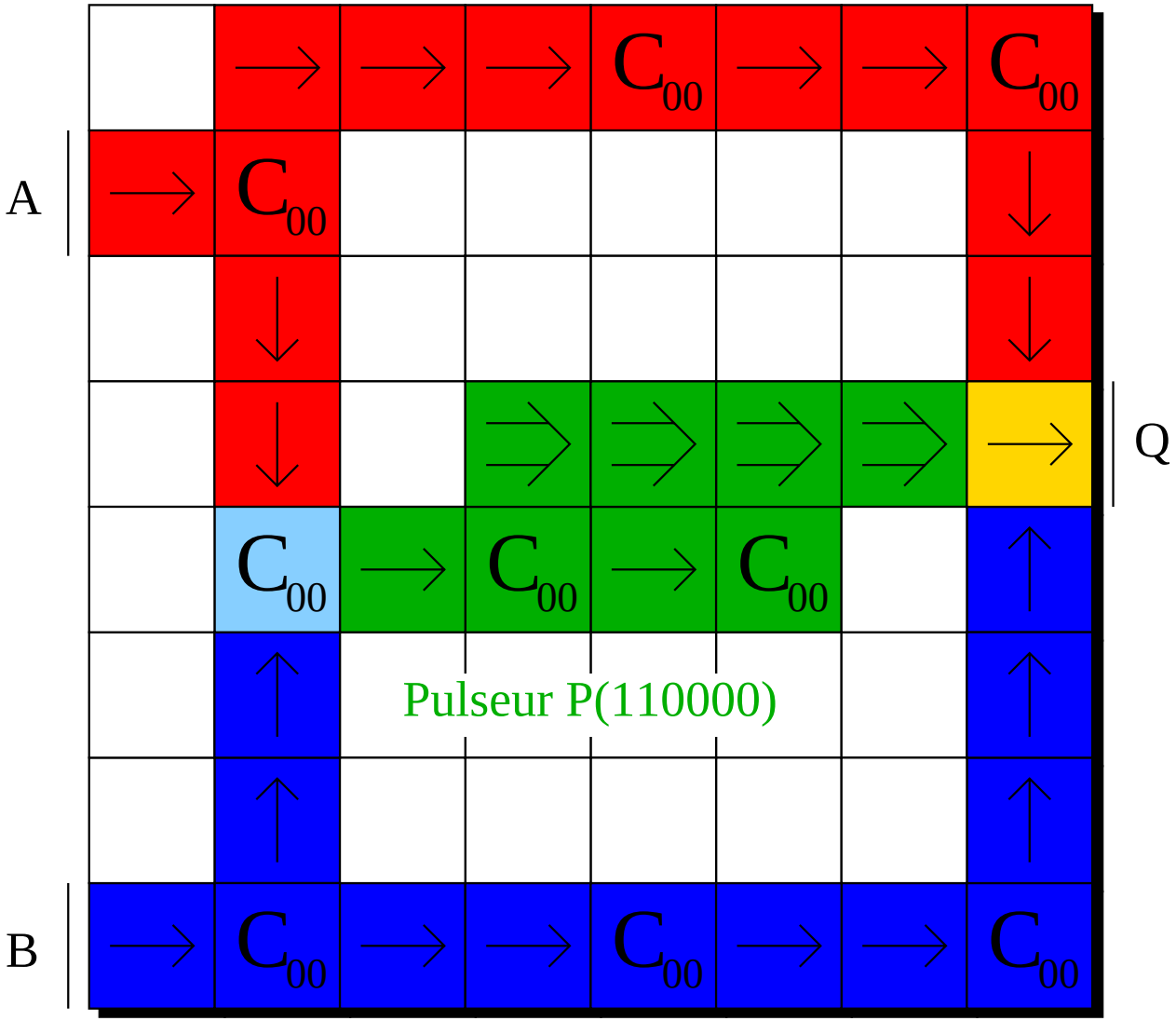

R
S
Q
C00
C00
C00
C00
C00
C00
C00
C00
P(11111)


P(11111)
R
S
Q
P(11111)

Application : la fonction XOR




A
B
Q
C00
C00
C00
C00
C00
C00


A
B
Q
C_{00}
C_{00}
C_{00}
C_{00}
C_{00}
C_{00}
C_{00}
C_{00}
C_{00}
Pulseur P(110000)