Résolution de niveaux du Sokoban

PoulpoGaz, darth-mole

16 mai 2023

Candidat n° 012345

Plan

Le jeu du Sokoban

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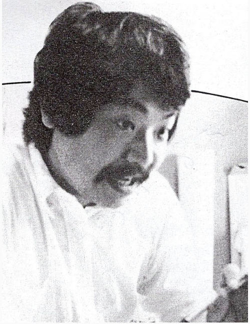
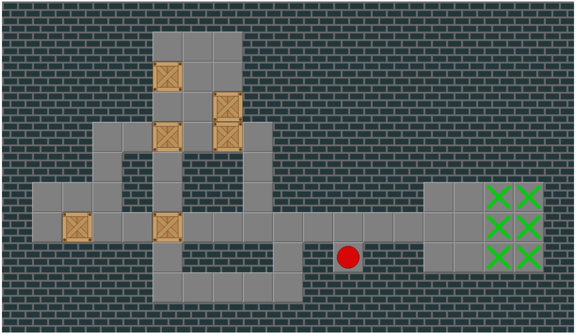


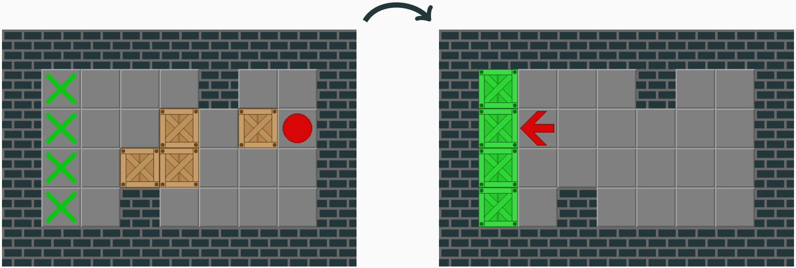
Hiroyuki Imabayashi



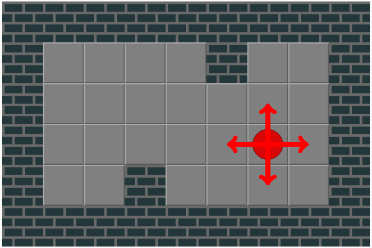
XSokoban

But du jeu

Déplacements

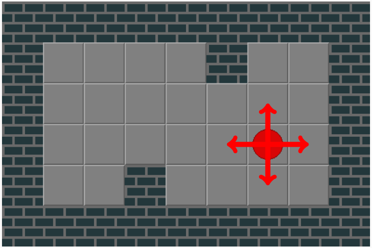


Règles

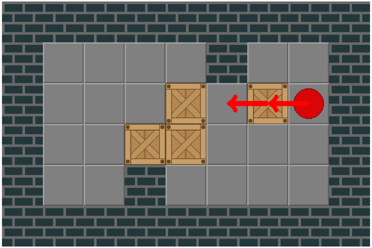


Déplacements autorisés

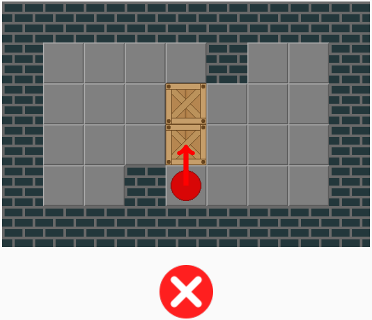
Règles

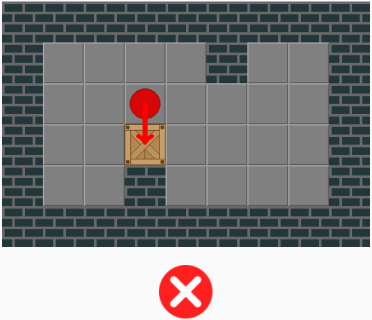


Déplacements autorisés

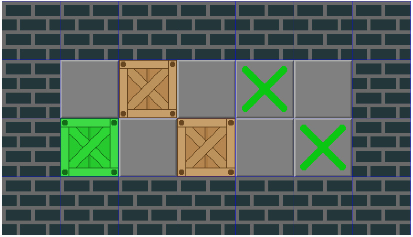


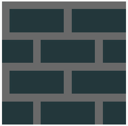
Règles



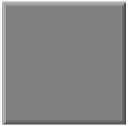


Tuiles

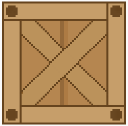




Mur



Sol



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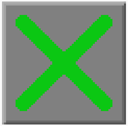
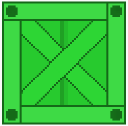


Cible



Caisse sur une cible

Problématique et réalisation

Quelles stratégies adopter pour trouver une solution le plus rapidement possible à un niveau de Sokoban ?

```
Welcome to sokoshell - Version 1.0-SNAPSHOT
Type 'help' to show help. More help for a command with 'help command'
sokoshell>
```

Lien avec le thème de l'année

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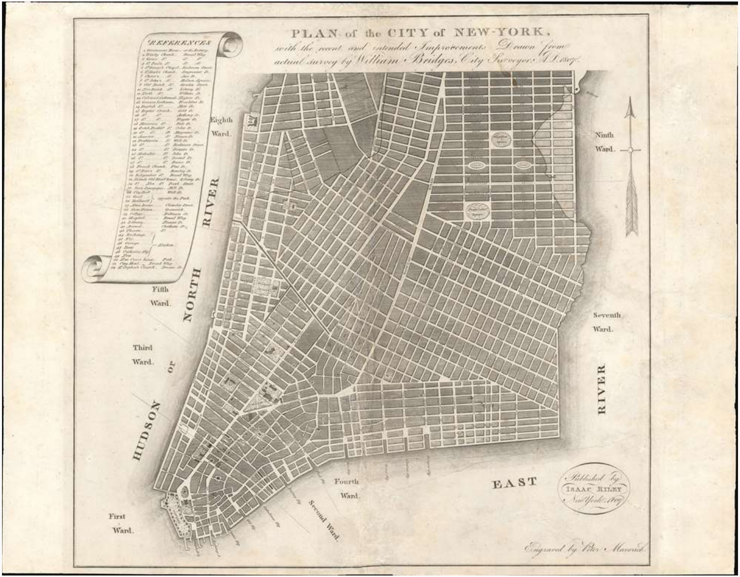
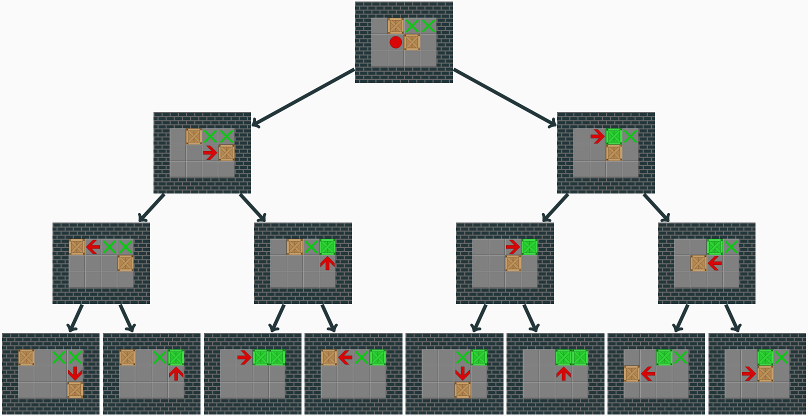
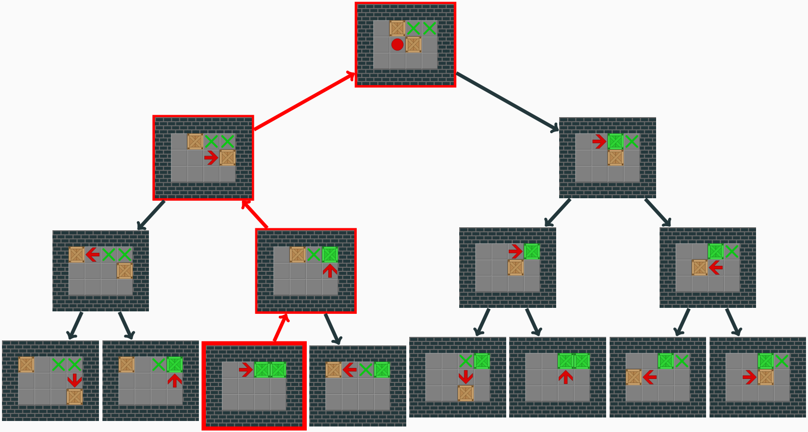


Principe de résolution

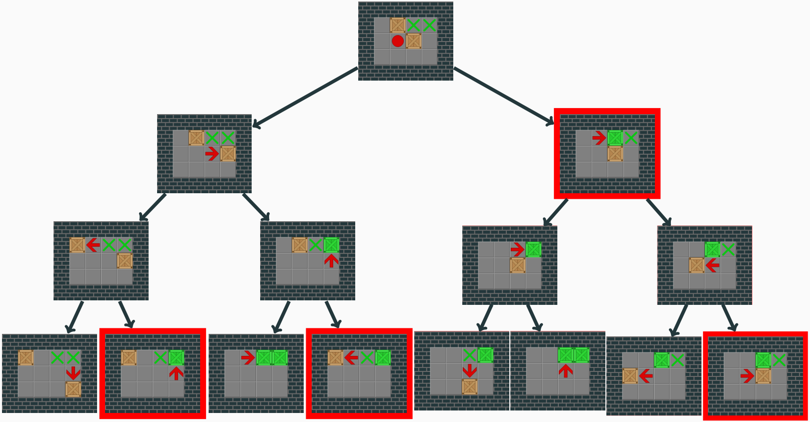
Arbre des états



Arbre des états



Arbre des états



Calcul du *hash* d'un état - Hash de Zobrist

Propriétés du **XOR** :

1. $a\,\textbf{XOR}\,a = 0$
2. **XOR** commutatif, associatif
3. **XOR** préserve l'aléatoire

Initialisation :

$$\begin{array}{cc} & \begin{array}{ccc} \text{caisse} & \text{joueur} & \text{case} \end{array} \\ T = & \begin{array}{c} \begin{pmatrix} 6357 & 5742 \\ -1378 & 42 \\ \vdots & \vdots \\ 93268 & -278 \end{pmatrix} \begin{array}{c} 0 \\ 1 \\ \vdots \\ wh-1 \end{array} \end{array} \end{array}$$

Calcul du *hash* d'un état - Hash de Zobrist

Usage : $(c_1, ..., c_n)$ n caisses et p position du joueur :

$$h = \underset{i=0}{\overset{n}{\textbf{XOR}}}\, T[c_i][0] \,\textbf{XOR}\, T[p][1]$$

Calculer le hash d'un état à l'aide de son parent : $c_i \rightarrow c_i', p \rightarrow p'$

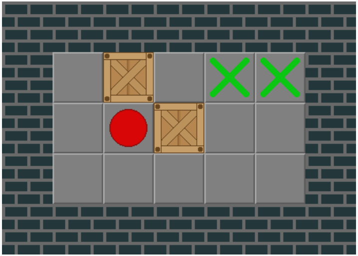
$$h' = h \,\textbf{XOR}\, T[c_i][0] \,\textbf{XOR}\, T[c_i'][0] \,\textbf{XOR}\, T[p][1] \,\textbf{XOR}\, T[p'][1]$$

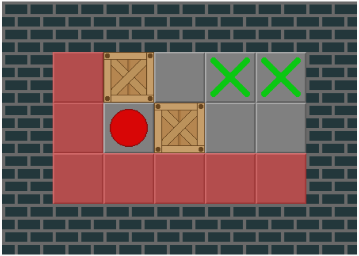
Réduction de l’espace de recherche

Réduction de l’espace de recherche

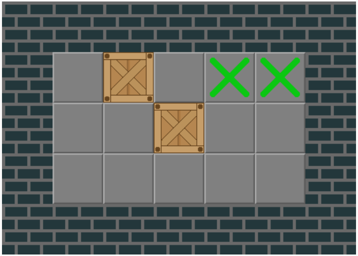
Analyse statique

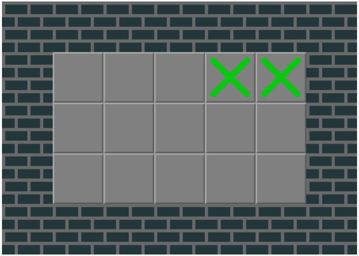
Détection des positions mortes *(dead positions)*





Détection des positions mortes *(dead positions)*





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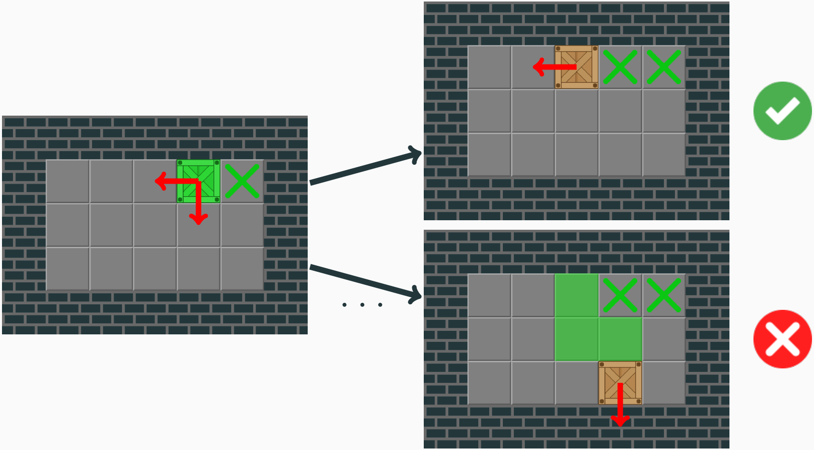
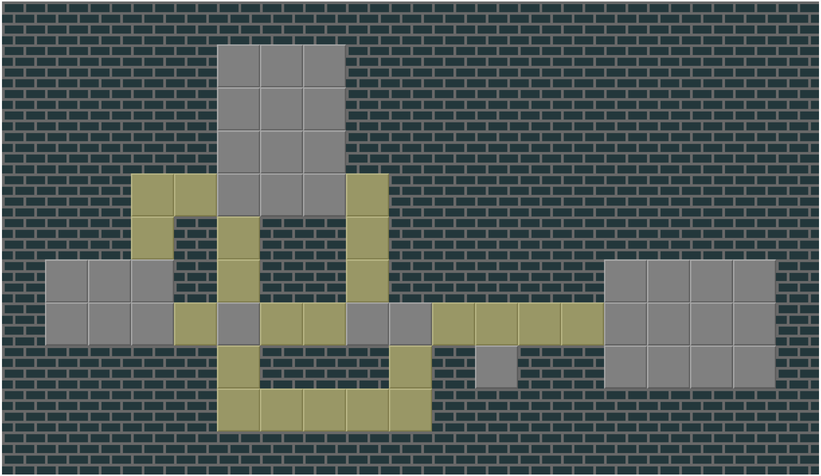
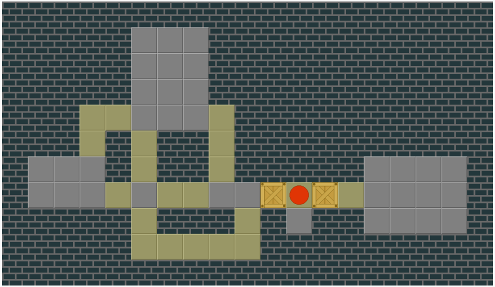
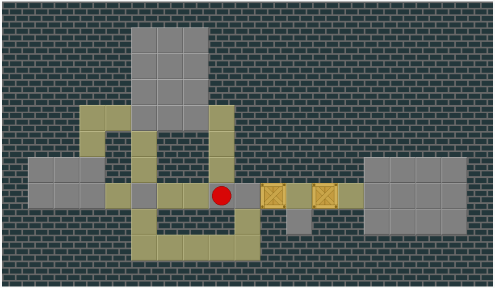


Détection de tunnels

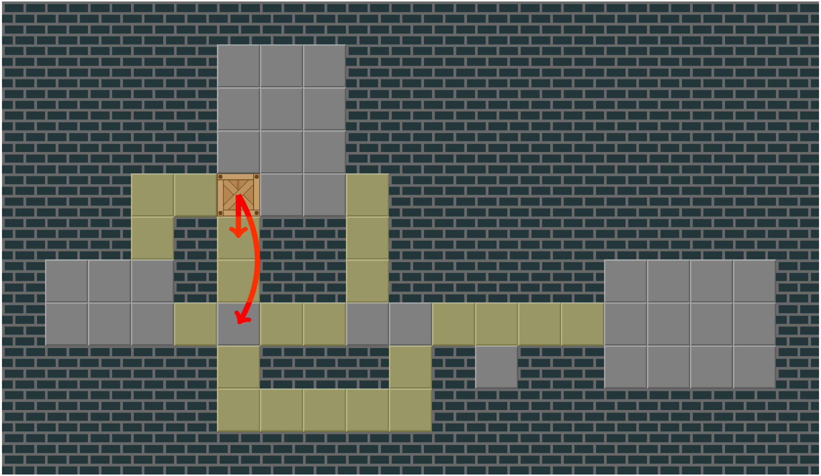


Détection de tunnels

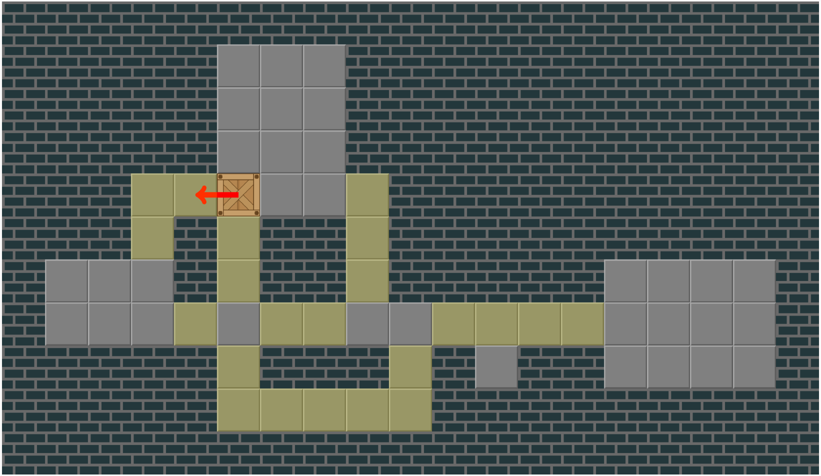




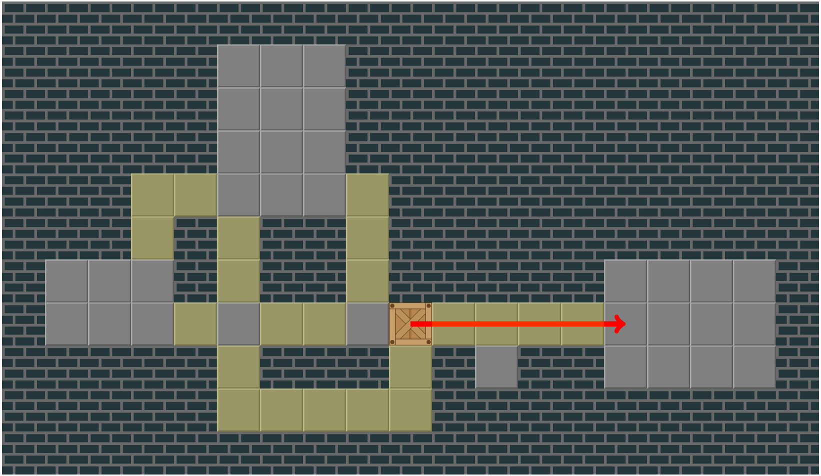
Détection de tunnels



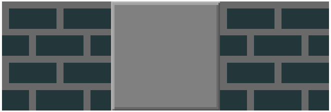
Détection de tunnels

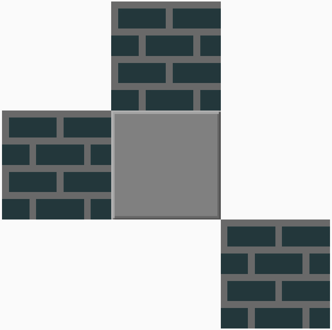


Détection de tunnels

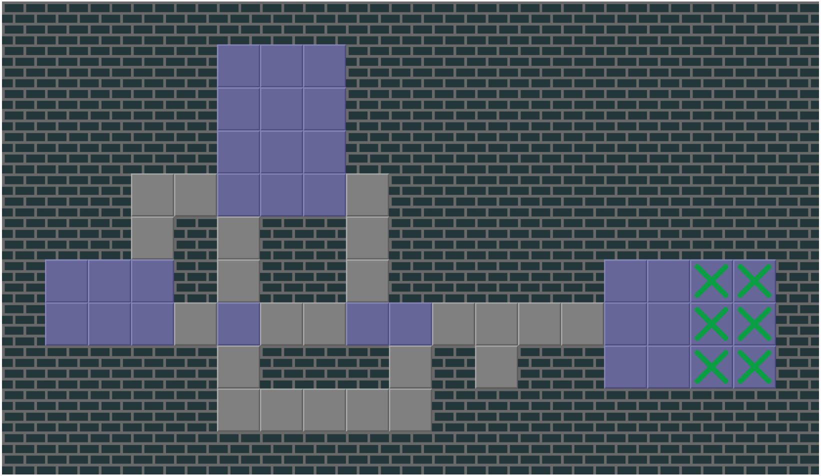


Détection de tunnels

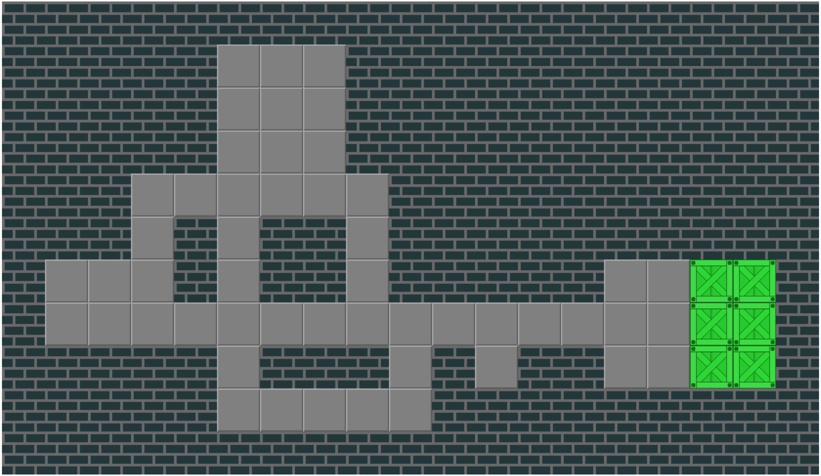




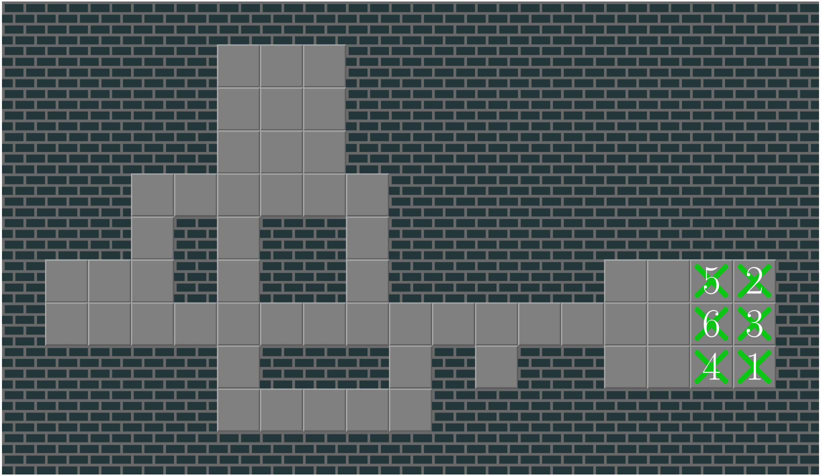
Salles et ordre de rangement *(packing order)*



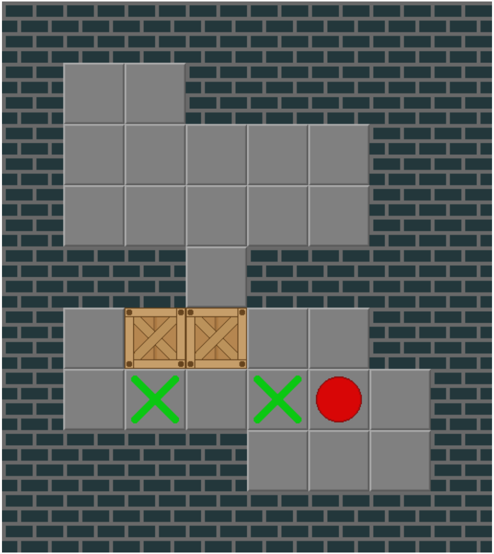
Salles et ordre de rangement *(packing order)*



Salles et ordre de rangement *(packing order)*



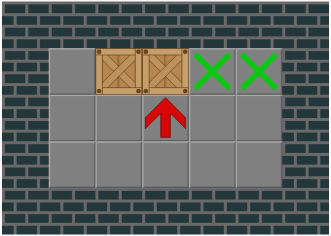
Salles et ordre de rangement *(packing order)*



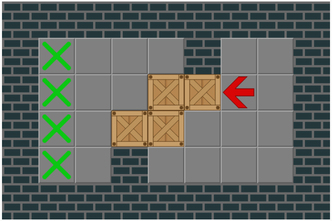
Réduction de l’espace de recherche

Analyse dynamique

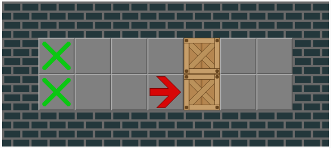
Détection d'impasses *(deadlocks)*



(a) *Freeze deadlock n°1*



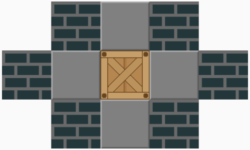
(b) *Freeze deadlock n°2*



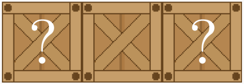
(c) *PI Corral deadlock*

Détection de *freeze deadlocks*

(a) *Règle n°1*

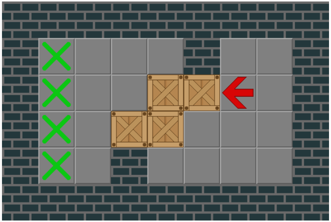


(b) *Règle n°2*

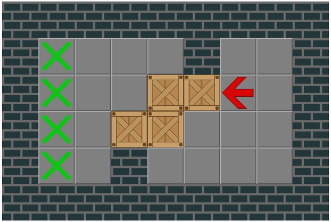


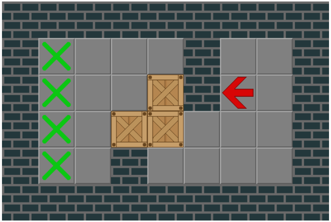
(c) *Règle n°3*

Détection de *freeze deadlocks*

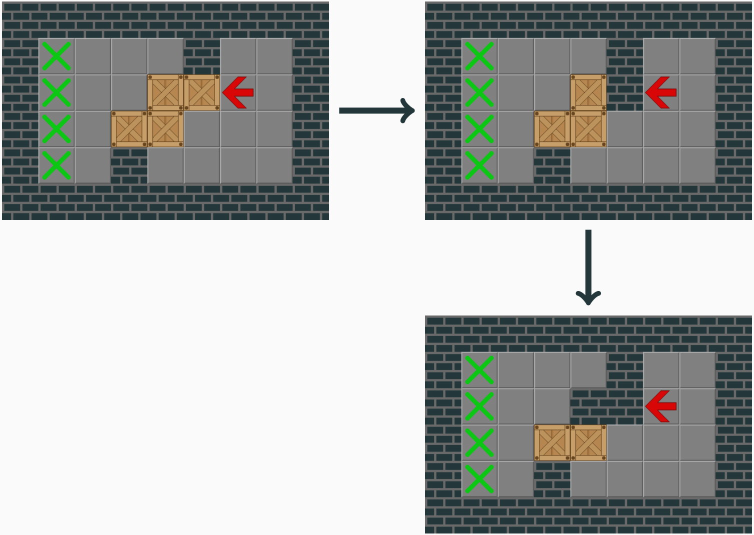


Détection de *freeze deadlocks*

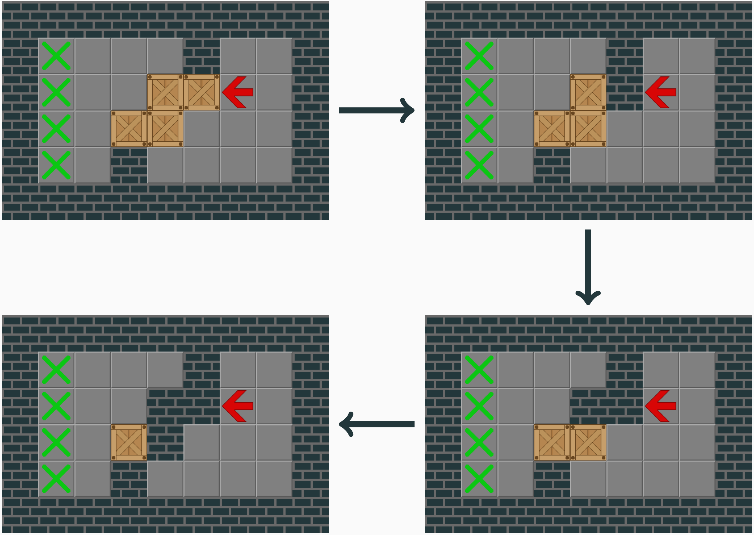




Détection de *freeze deadlocks*

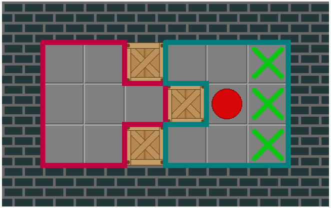


Détection de *freeze deadlocks*

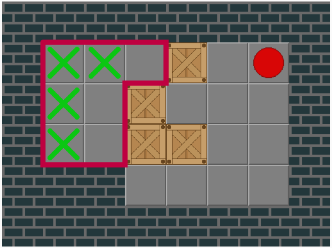


Gelée!

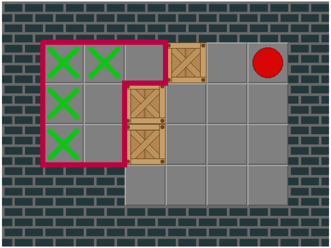
Détection de *PI Corral deadlocks*



(a) *Corral*

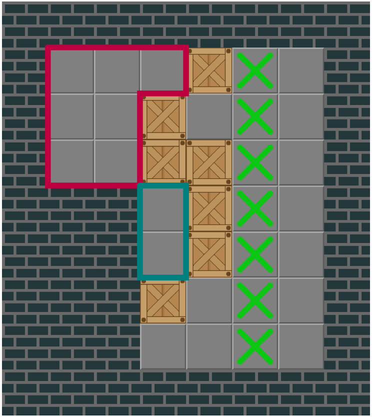


(b) *I Corral*



(c) *PI Corral*

Détection de *PI Corral deadlocks*



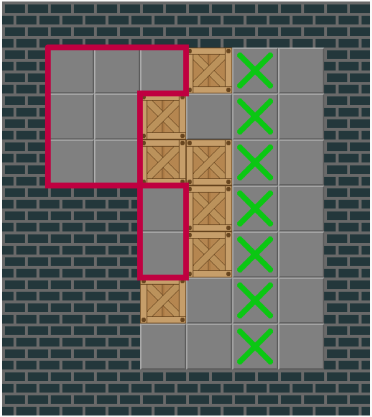
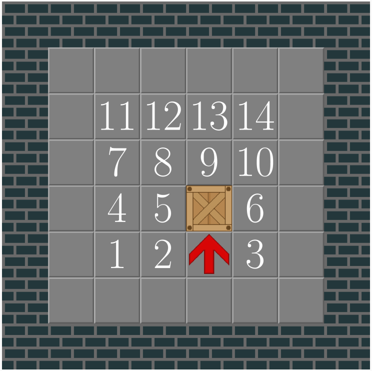
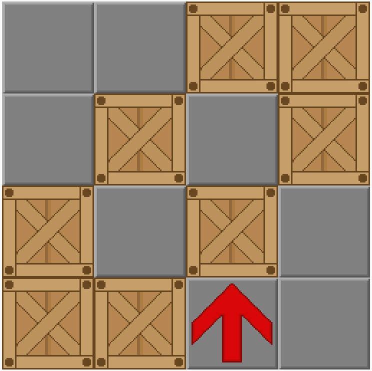


Table de *deadlocks*





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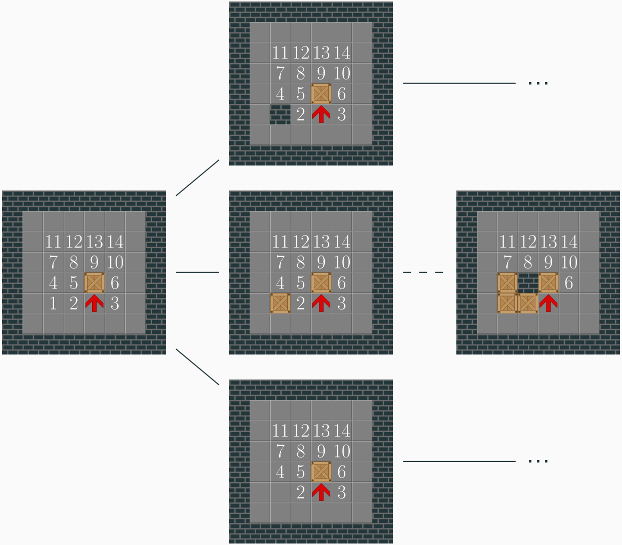
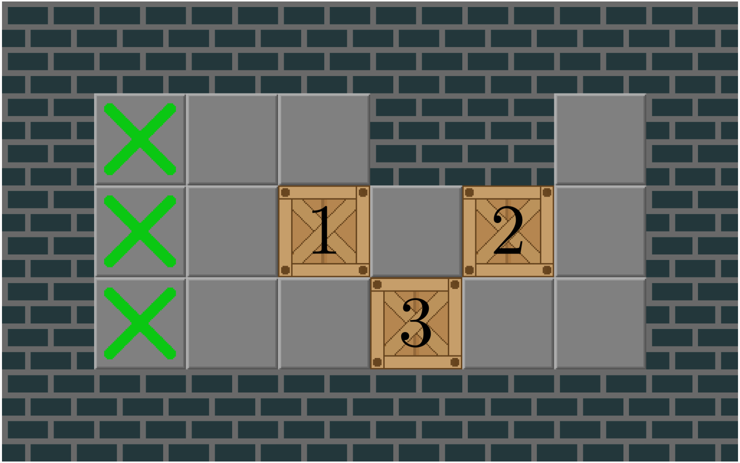
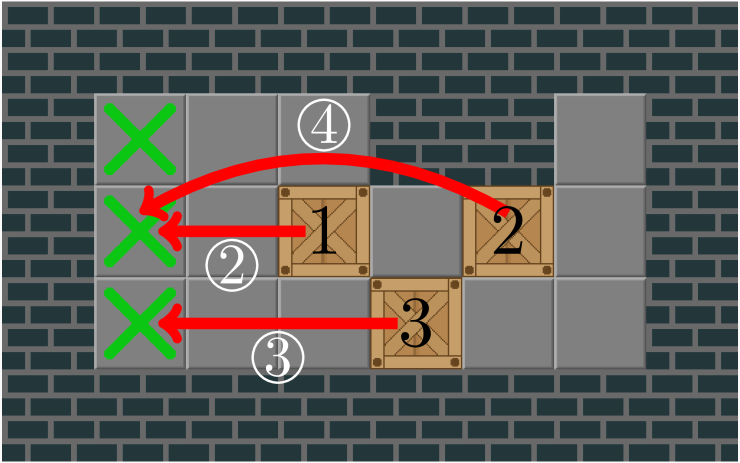


Recherche dirigée par une heuristique

Heuristique simple *(Simple Lower Bound)*

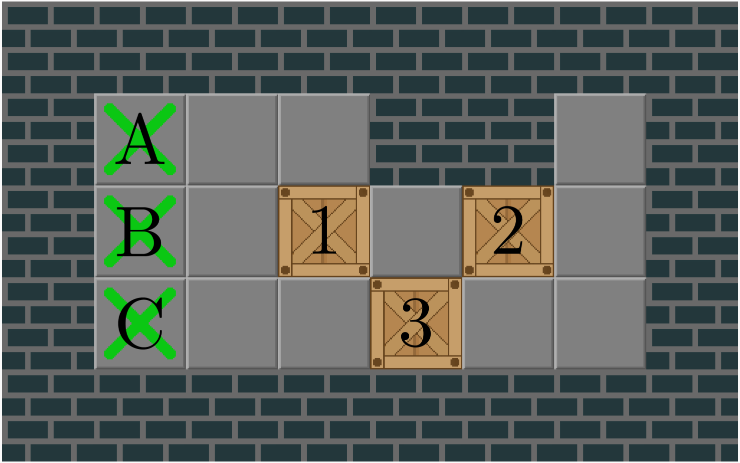


Heuristique simple *(Simple Lower Bound)*

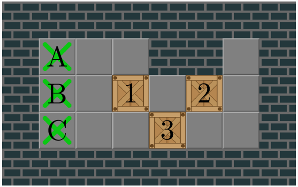


$$\boxed{2 + 4 + 3 = \mathbf{9}}$$

Heuristique gloutonne *(Greedy Lower Bound)*



Heuristique gloutonne *(Greedy Lower Bound)*

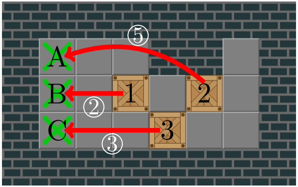


$1 \rightarrow A$	3
$1 \rightarrow B$	2
$1 \rightarrow C$	3
$2 \rightarrow A$	4
$2 \rightarrow B$	4
$2 \rightarrow C$	5
$3 \rightarrow A$	5
$3 \rightarrow B$	4
$3 \rightarrow C$	3

Tri $\longrightarrow$

1 → B	**2**
$1 \rightarrow A$	3
$1 \rightarrow C$	3
3 → C	**3**
$2 \rightarrow B$	4
$3 \rightarrow B$	4
$2 \rightarrow A$	5
$2 \rightarrow C$	5
3 → A	**5**

Heuristique gloutonne *(Greedy Lower Bound)*



$\boxed{2+3+5=\mathbf{10}}$

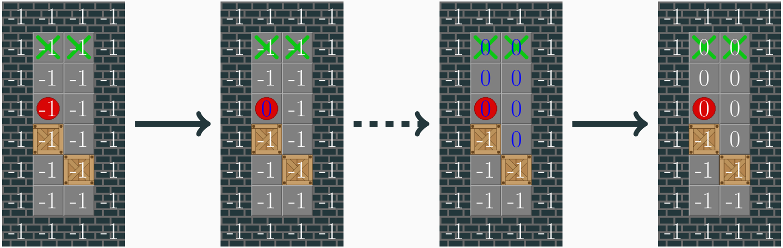
$1 \rightarrow A$	3
$1 \rightarrow B$	2
$1 \rightarrow C$	3
$2 \rightarrow A$	4
$2 \rightarrow B$	4
$2 \rightarrow C$	5
$3 \rightarrow A$	5
$3 \rightarrow B$	4
$3 \rightarrow C$	3

$\xrightarrow{\text{Tri}}$

$\mathbf{1 \rightarrow B}$	**2**
$1 \rightarrow A$	3
$1 \rightarrow C$	3
$\mathbf{3 \rightarrow C}$	**3**
$2 \rightarrow B$	4
$3 \rightarrow B$	4
$2 \rightarrow A$	5
$2 \rightarrow C$	5
$\mathbf{3 \rightarrow A}$	**5**

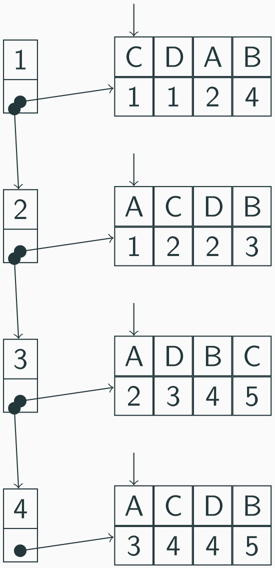
Optimisations

Parcours de graphes : démarquer tous les noeuds en $\mathcal{O}(1)$



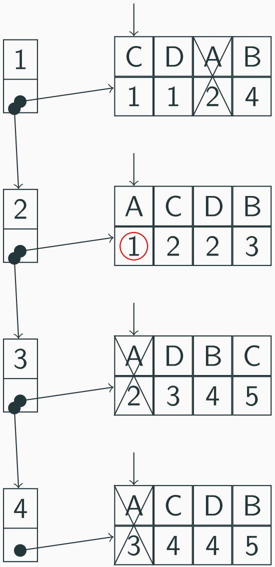
$m = 0$ $\quad$ $m = 0$ $\quad$ $m = 0$ $\quad$ $m = 1$

Greedy Lower Bound en $\mathcal{O}(n^2)$



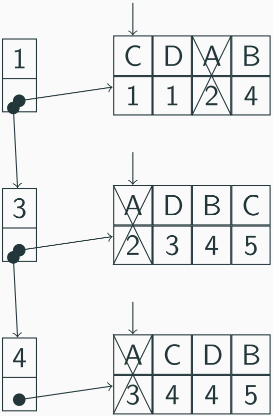
$h =$

Greedy Lower Bound en $\mathcal{O}(n^2)$



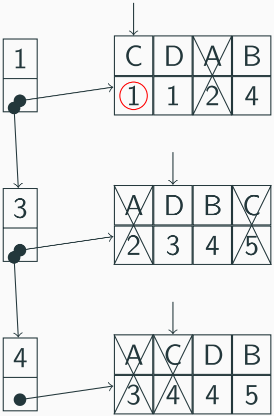
$h = 1+$

Greedy Lower Bound en $\mathcal{O}(n^2)$



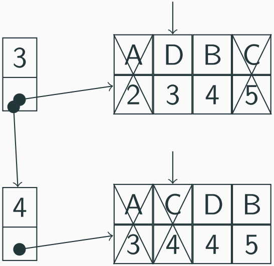
$h = 1+$

Greedy Lower Bound en $\mathcal{O}(n^2)$



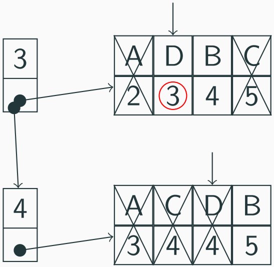
$h = 1 + 1 +$

Greedy Lower Bound en $\mathcal{O}(n^2)$



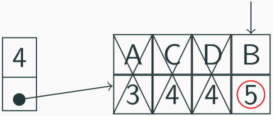
$$h = 1 + 1 +$$

Greedy Lower Bound en $\mathcal{O}(n^2)$



$h = 1 + 1 + 3 +$

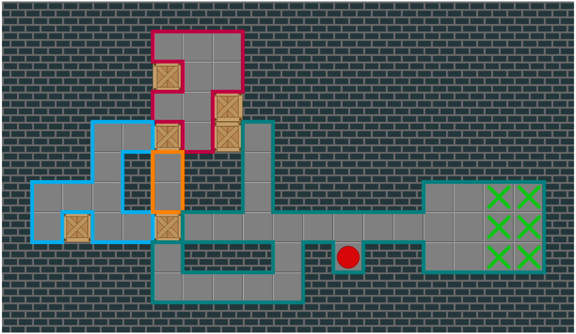
Greedy Lower Bound en $\mathcal{O}(n^2)$



$$h = 1 + 1 + 3 + 5 = 10$$

Calcul des *corrals* en $\mathcal{O}(wh)$

Utilisation de *Union-Find* : partition de $[\![0; wh-1]\!]$.



Calcul des *corrals* en $\mathcal{O}(wh)$

```
procedure CORRAL(x, y)
    if not solid(x,y) then
        createSingleton(x, y)
    else
        if solid(x-1, y) and solid(x,y-1) then
            createSingleton(x, y)
        else if not solid(x-1, y) and solid(x,y-1) then
            addToCorral(x-1,y, x,y)
        else if solid(x-1, y) and not solid(x,y-1) then
            addToCorral(x,y-1, x,y)
        else
            addToCorral(x-1,y, x,y)
            union(x,y-1, x,y)
        end if
    end if
```

Résultats

Nombre de niveaux résolus

Collection	Nombre de niveaux	A*	fess0	Festival	Sokolution	Takaken	YASS
XSokoban	90	11	15	90	90	90	89
Large test suite	3272	2204	2273	3202	3130	2944	2865

Annexe

Tableau des complexités