

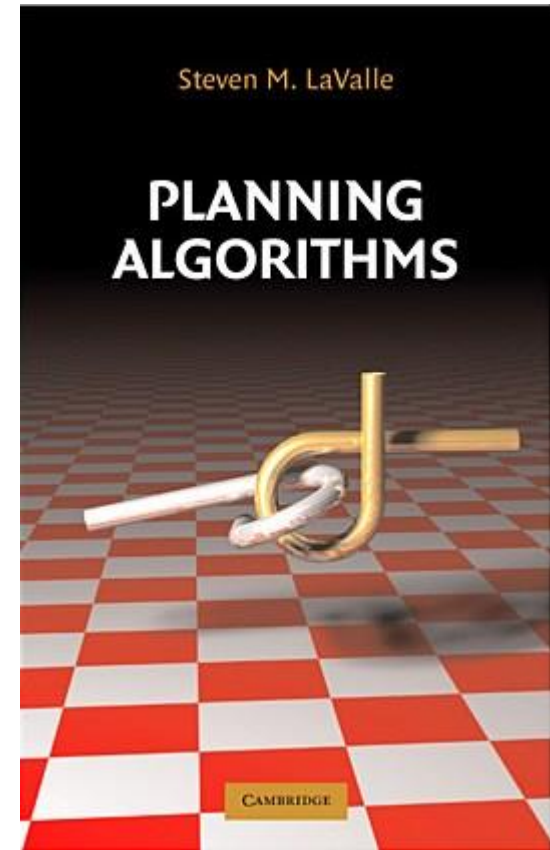
Méthodes probabilistes

- Basée sur l'échantillonnage au hasard de configurations dans C_{libre} .
- Besoin d'une fonction de détection de collision
 - plus besoin de calculer le C_{libre} au complet
 - fonction très optimisée
- Approches
 - **Requête simple** : RRT-Connect
 - basée sur les Rapidely-exploring Random Trees (RRT)
 - **Requête multiple** : Probabilistic Road Maps (RPM)

Handbook of Robotics, p. 112, Springer.

Rapidly-exploring Random Trees (RRT)

- Pour recherche exploratoire dans des espaces à haute dimensionnalité
- Développé par Steven M. LaValle et James Kuffner
- Construire un arbre de façon incrémentale, pour minimiser la distance entre un point choisis au hasard et l'arbre



<http://planning.cs.uiuc.edu/>

Rapidly-exploring Random Trees (RRT)

```
for k = 1 to K  
   $q_{\text{rand}} \leftarrow \text{RAND\_CONF}()$   
   $q_{\text{near}} \leftarrow \text{NEAREST\_VERTEX}(q_{\text{rand}}, G)$   
   $q_{\text{new}} \leftarrow \text{NEW\_CONF}(q_{\text{near}}, \Delta q)$   
  G.add_vertex( $q_{\text{new}}$ )  
  G.add_edge( $q_{\text{near}}, q_{\text{new}}$ )  
end
```

K : nombre d'itérations

G : graphe de l'arbre

- arbre au départ (1 seul sommet)

Rapidly-exploring Random Trees (RRT)

```
for k = 1 to K
```

```
   $q_{rand} \leftarrow \text{RAND\_CONF}()$ 
```

```
   $q_{near} \leftarrow \text{NEAREST\_VERTEX}(q_{rand}, G)$ 
```

```
   $q_{new} \leftarrow \text{NEW\_CONF}(q_{near}, \Delta q)$ 
```

```
  G.add_vertex( $q_{new}$ )
```

```
  G.add_edge( $q_{near}, q_{new}$ )
```

```
end
```

q_{rand}
● sommet tiré au hasard



Rapidly-exploring Random Trees (RRT)

```
for k = 1 to K
```

```
   $q_{\text{rand}} \leftarrow \text{RAND\_CONF}()$ 
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```
   $q_{\text{near}} \leftarrow \text{NEAREST\_VERTEX}(q_{\text{rand}}, G)$ 
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```
   $q_{\text{new}} \leftarrow \text{NEW\_CONF}(q_{\text{near}}, \Delta q)$ 
```

```
  G.add_vertex( $q_{\text{new}}$ )
```

```
  G.add_edge( $q_{\text{near}}, q_{\text{new}}$ )
```

```
end
```



q_{near} sommet le plus proche de l'arbre G

Rapidly-exploring Random Trees (RRT)

```
for k = 1 to K
```

```
   $q_{rand} \leftarrow \text{RAND\_CONF}()$ 
```

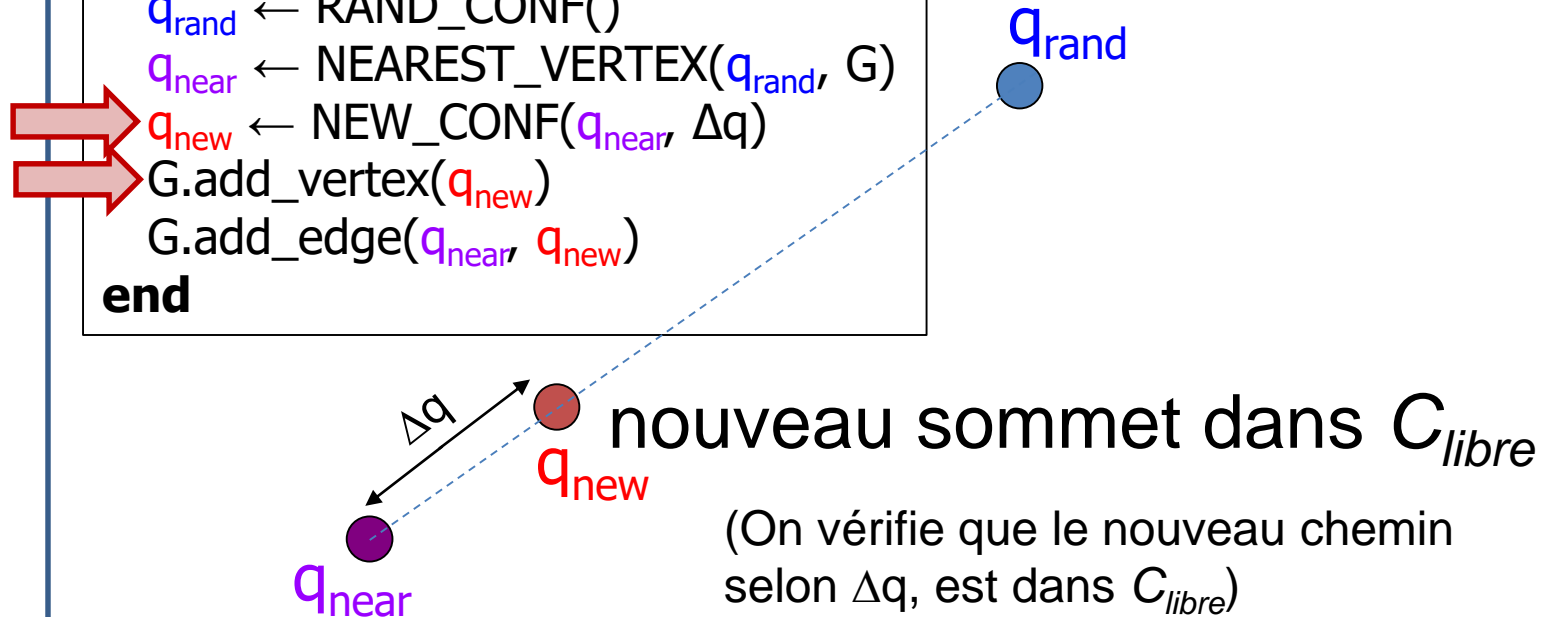
```
   $q_{near} \leftarrow \text{NEAREST\_VERTEX}(q_{rand}, G)$ 
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   $q_{new} \leftarrow \text{NEW\_CONF}(q_{near}, \Delta q)$ 
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```
  G.add_edge( $q_{near}, q_{new}$ )
```

```
end
```



Rapidly-exploring Random Trees (RRT)

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for k = 1 to K
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   $q_{\text{rand}} \leftarrow \text{RAND\_CONF}()$ 
```

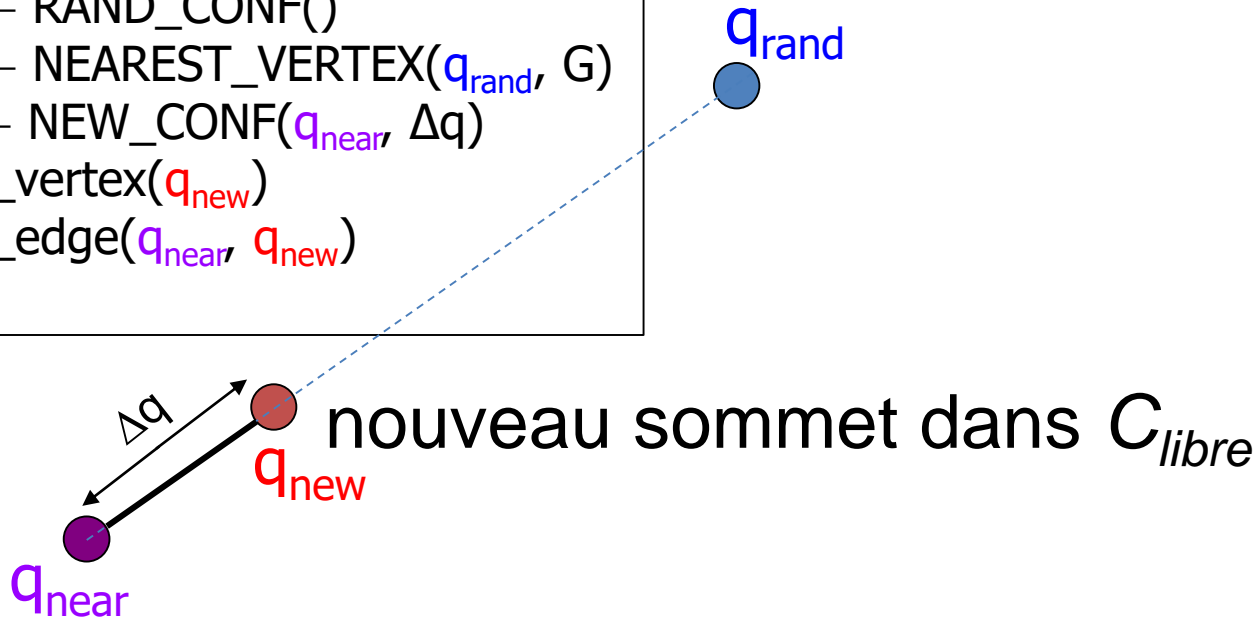
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```

```
   $q_{\text{new}} \leftarrow \text{NEW\_CONF}(q_{\text{near}}, \Delta q)$ 
```

```
  G.add_vertex( $q_{\text{new}}$ )
```

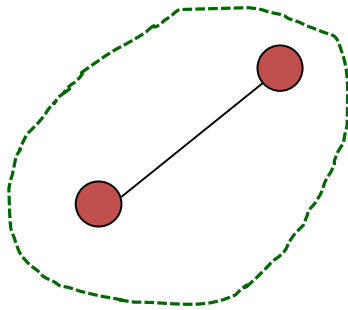
```
  G.add_edge( $q_{\text{near}}, q_{\text{new}}$ )
```

```
end
```



Rapidly-exploring Random Trees (RRT)

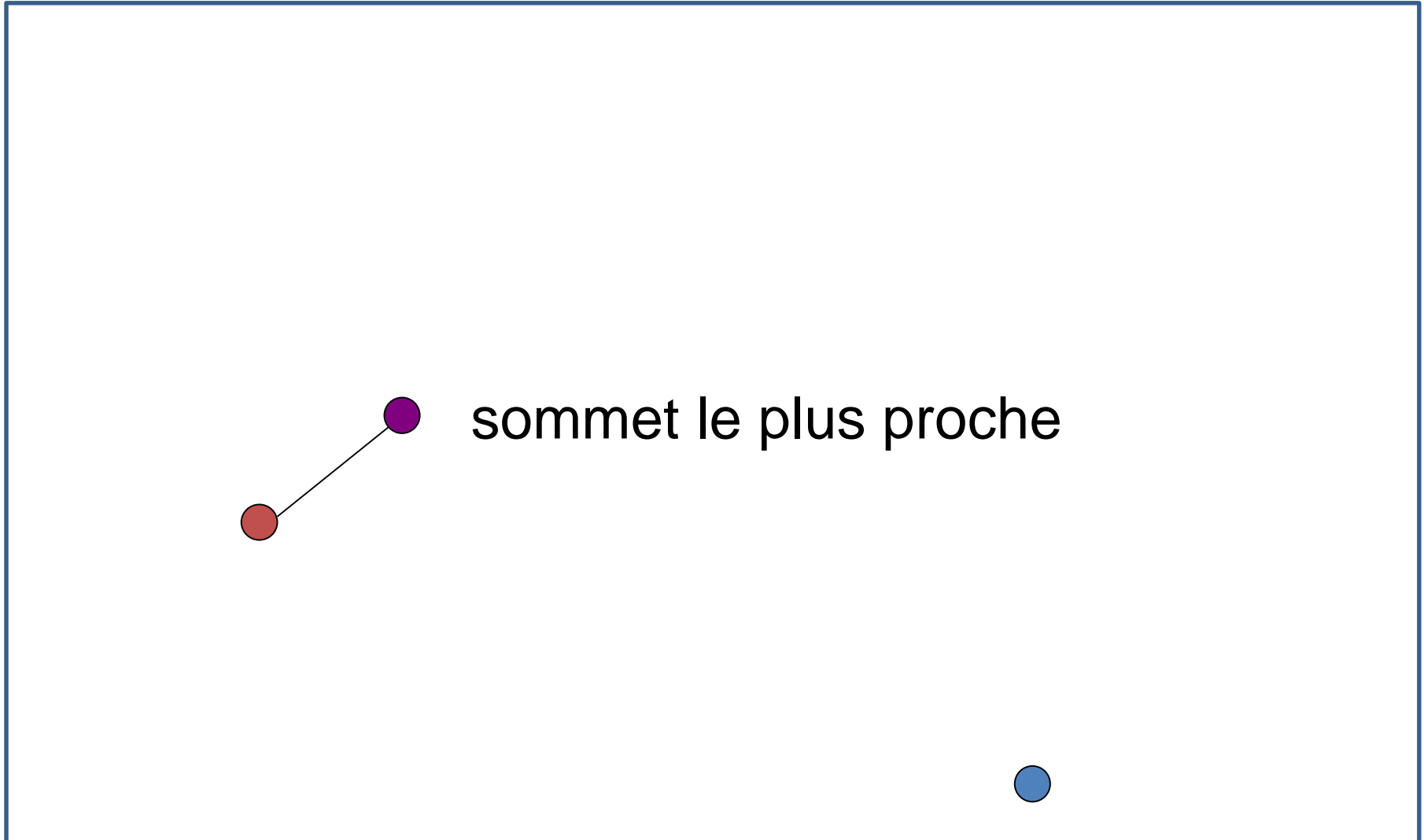
Arbre G



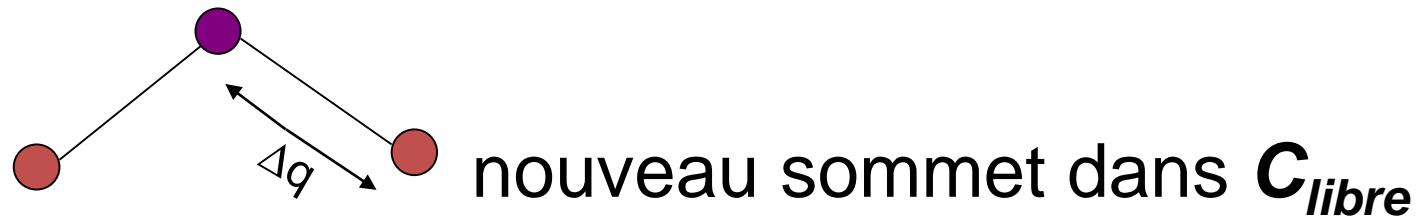
autre sommet tiré au hasard



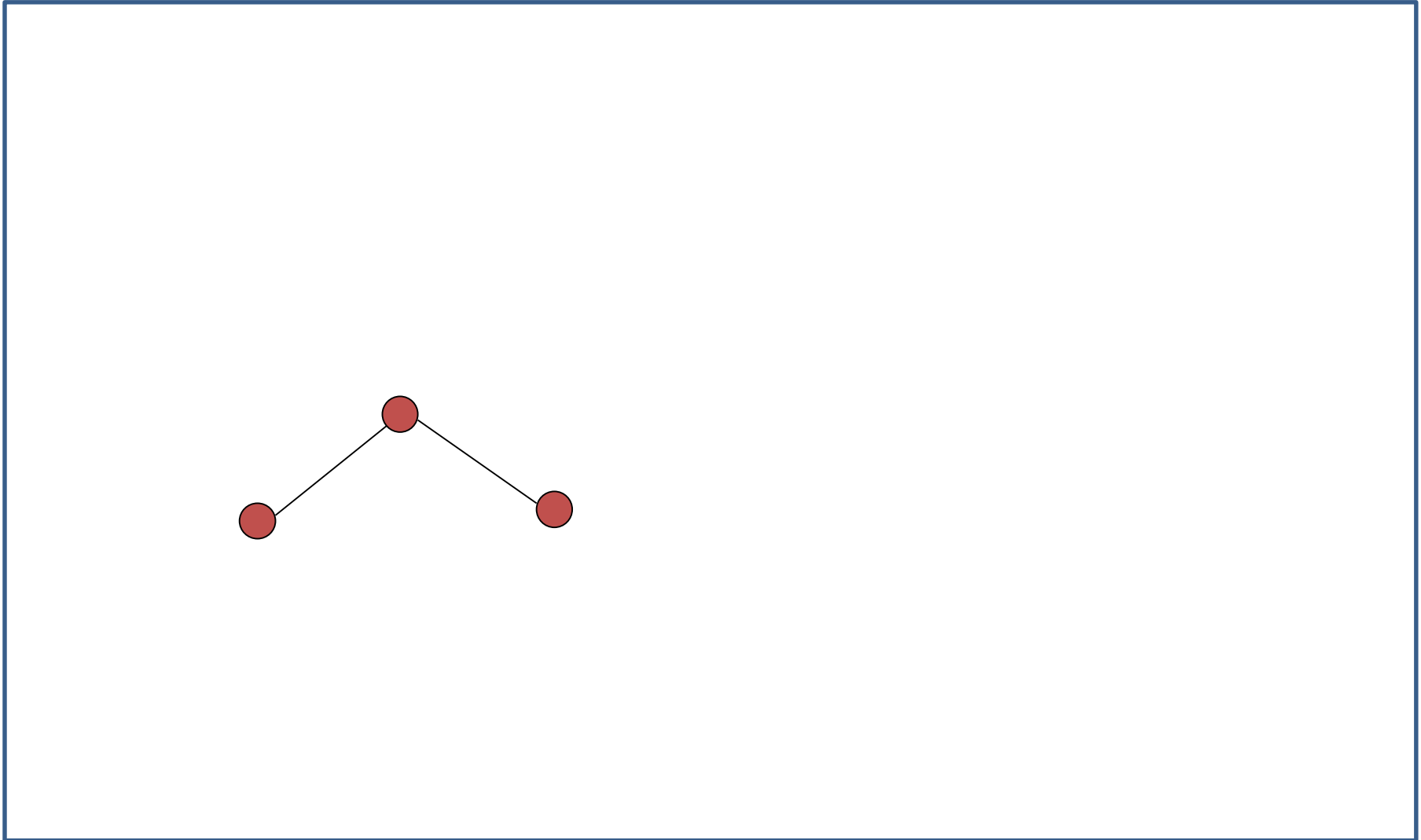
Rapidly-exploring Random Trees (RRT)



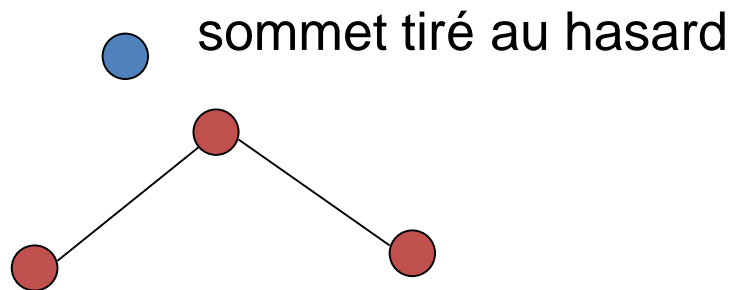
Rapidly-exploring Random Trees (RRT)



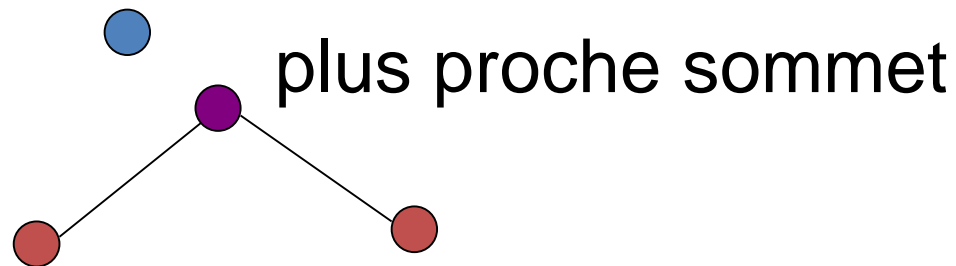
Rapidly-exploring Random Trees (RRT)



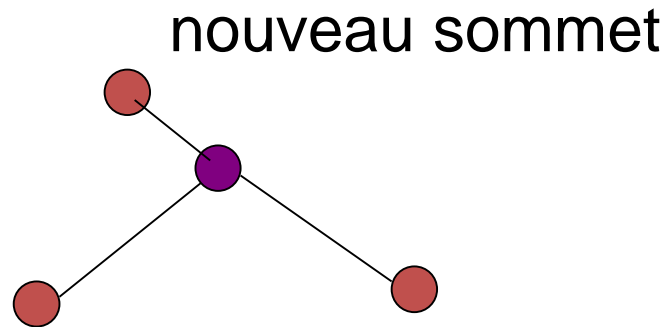
Rapidly-exploring Random Trees (RRT)



Rapidly-exploring Random Trees (RRT)



Rapidly-exploring Random Trees (RRT)



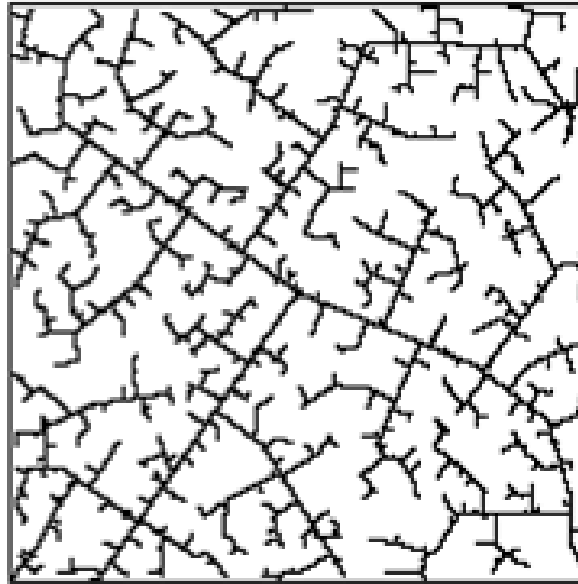
et ainsi de suite...

Rapidly-exploring Random Trees (RRT)

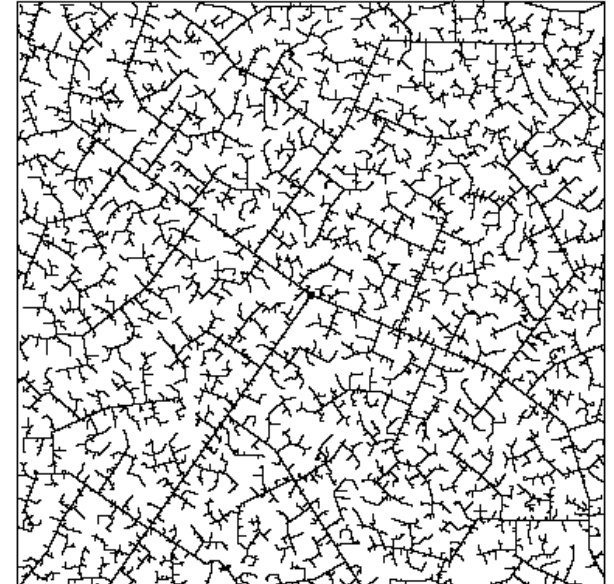
- Tend à bien remplir l'espace vide



45 itérations



390 itérations



2345 itérations

RRT-Connect

- Croître deux arbres, l'un partant de la configuration de départ et l'autre d'arrivée
- À chaque tirage, on essaie de connecter un des arbres avec l'autre, de façon vorace

RRT-Connect: exemple

Phase croissance de l'arbre

● Départ



○ Arrivée

RRT-Connect: exemple

Phase croissance de l'arbre

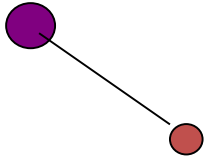


● sommet tiré au hasard

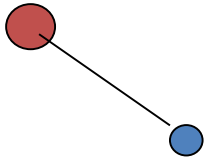


RRT-Connect: exemple

Phase croissance de l'arbre

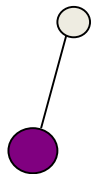
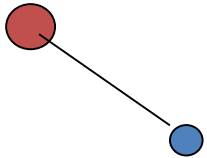


RRT-Connect: exemple



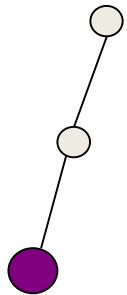
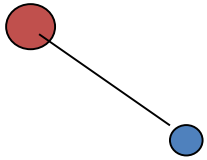
On essaie maintenant de
connecter l'arbre du bas vers
l'arbre du haut, de façon
vorace (greedy)

RRT-Connect: exemple



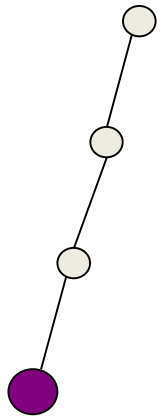
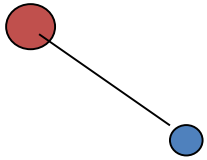
Phase connexion des arbres

RRT-Connect: exemple



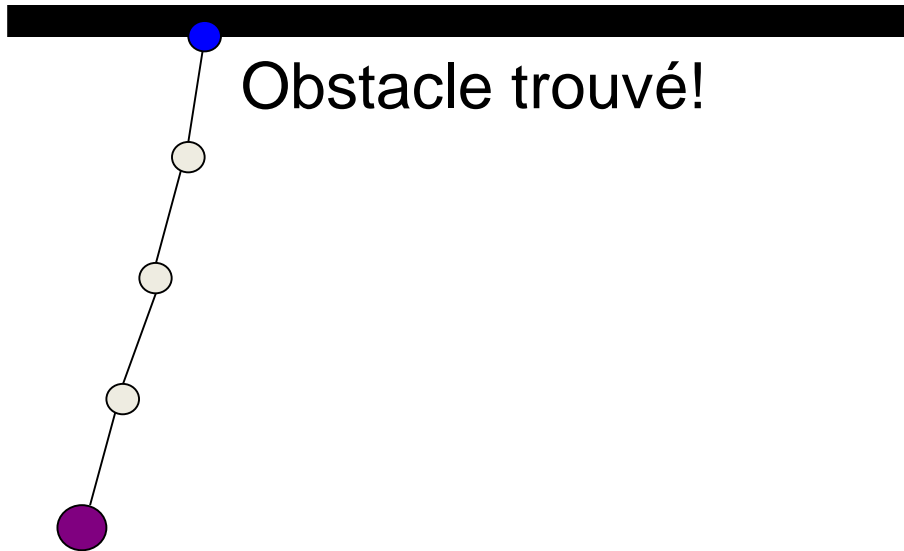
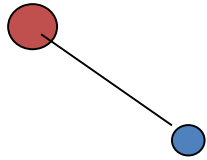
Phase connexion des arbres

RRT-Connect: exemple



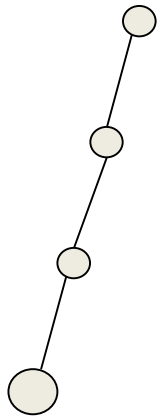
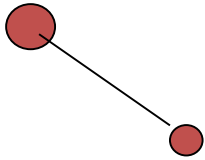
Phase connexion des arbres

RRT-Connect: exemple



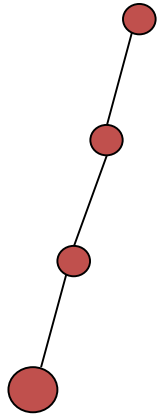
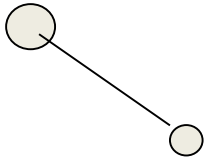
Phase connexion des arbres

RRT-Connect: exemple



On inverse les rôles!

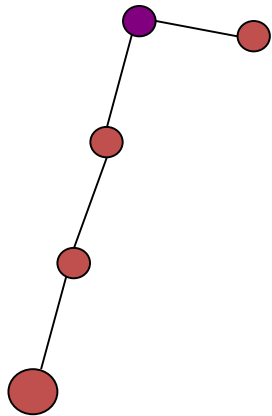
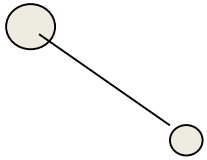
RRT-Connect: exemple



On inverse les rôles!

Phase croissance de l'arbre

RRT-Connect: exemple

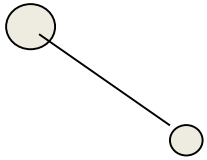


on tire un point au hasard, ajoute
un sommet à l'arbre du bas

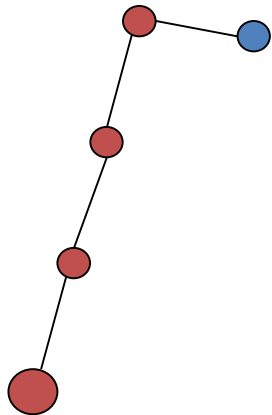
Phase croissance de l'arbre

RRT-Connect: exemple

Phase connexion des arbres

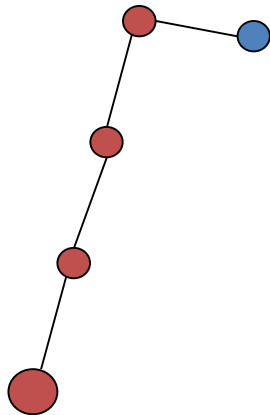
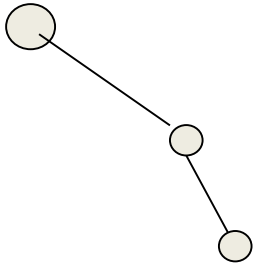


Et de façon vorace on croît l'arbre du haut



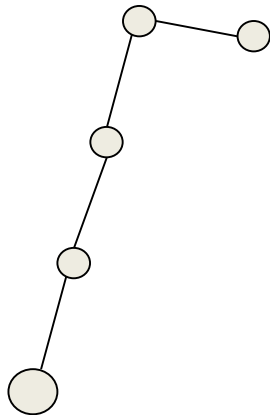
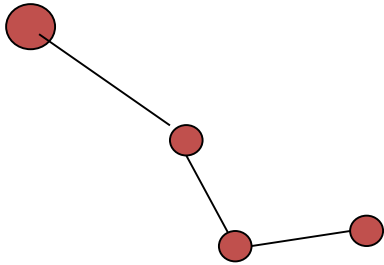
RRT-Connect: exemple

Phase connexion des arbres

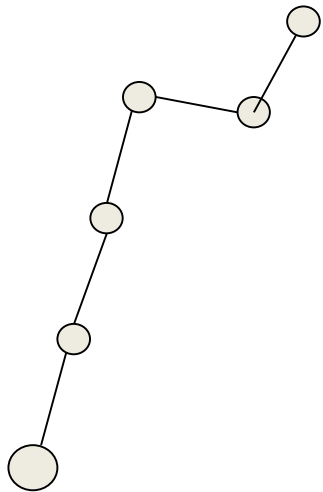
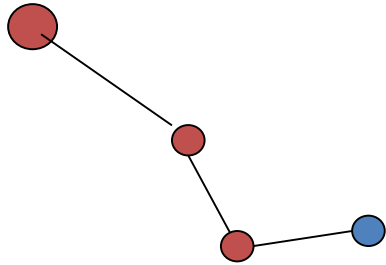


RRT-Connect: exemple

Phase croissance de l'arbre

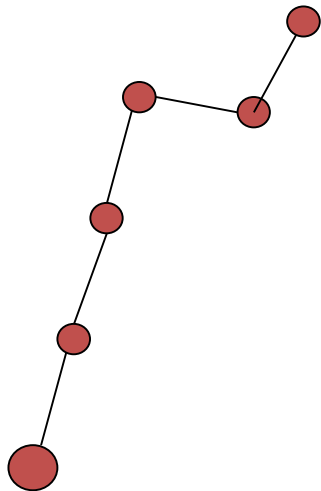
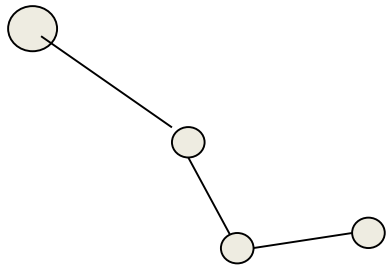


RRT-Connect: exemple



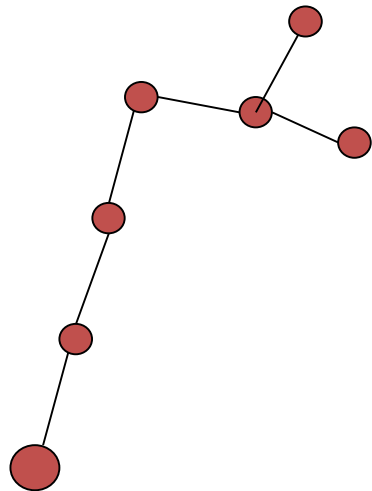
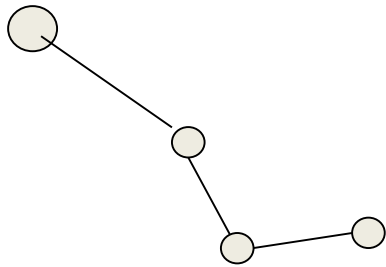
Phase connexion des arbres

RRT-Connect: exemple



Phase croissance de l'arbre

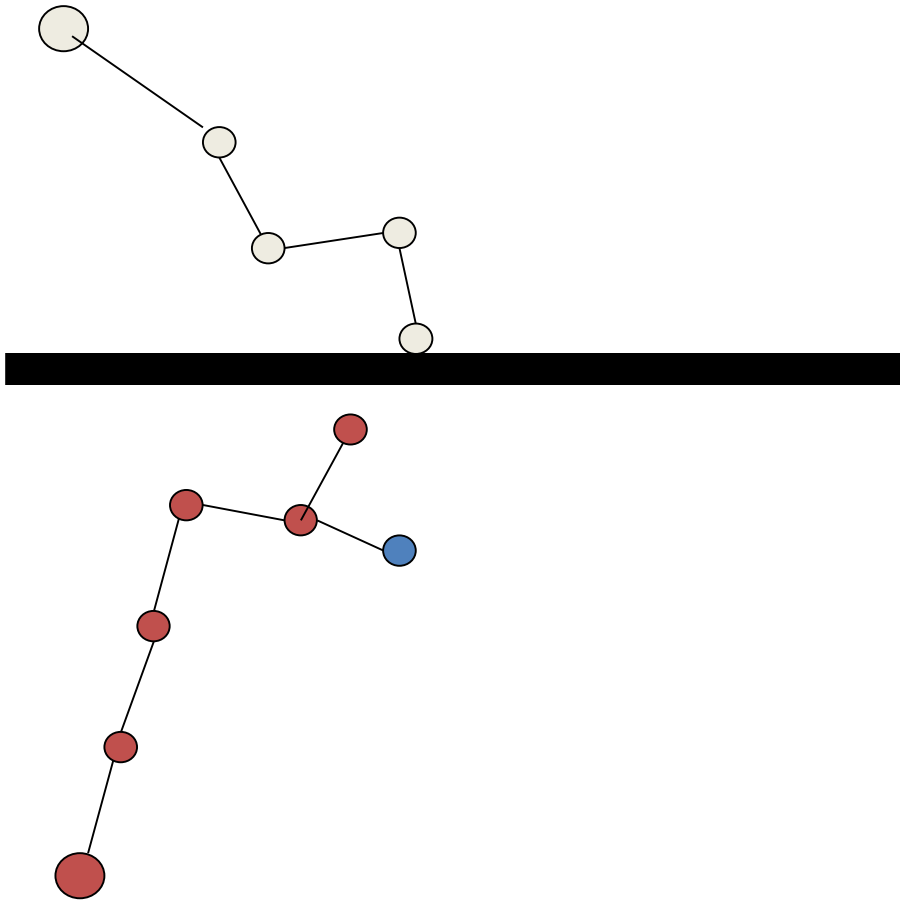
RRT-Connect: exemple



Phase croissance de l'arbre

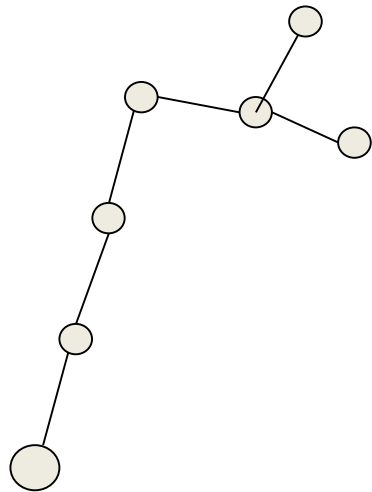
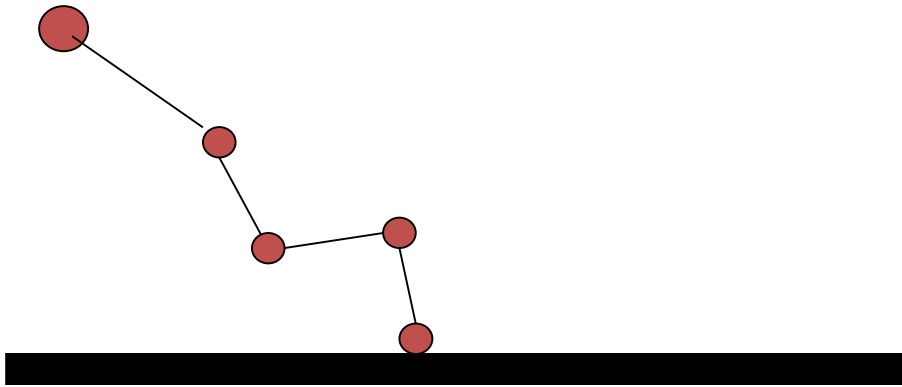
RRT-Connect: exemple

Phase connexion des arbres



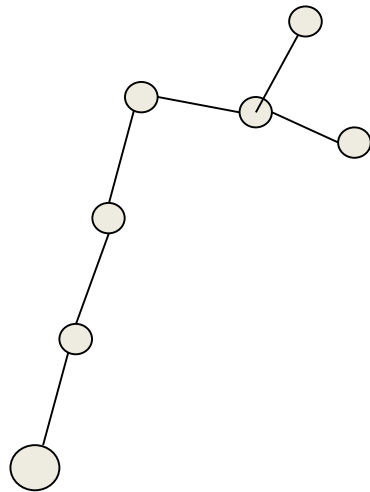
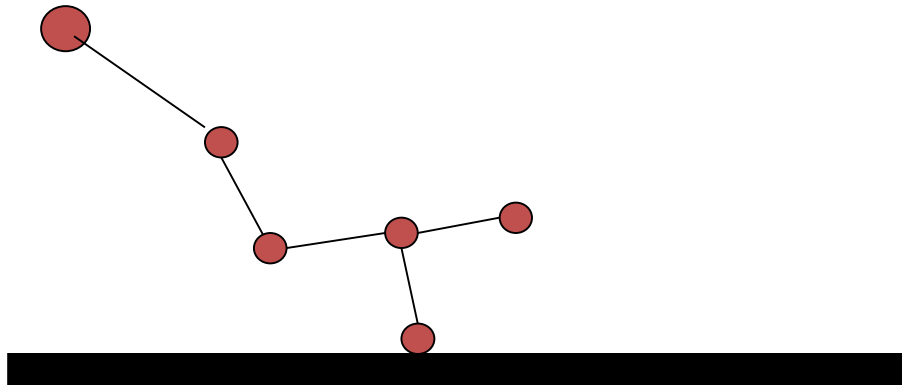
RRT-Connect: exemple

Phase croissance de l'arbre

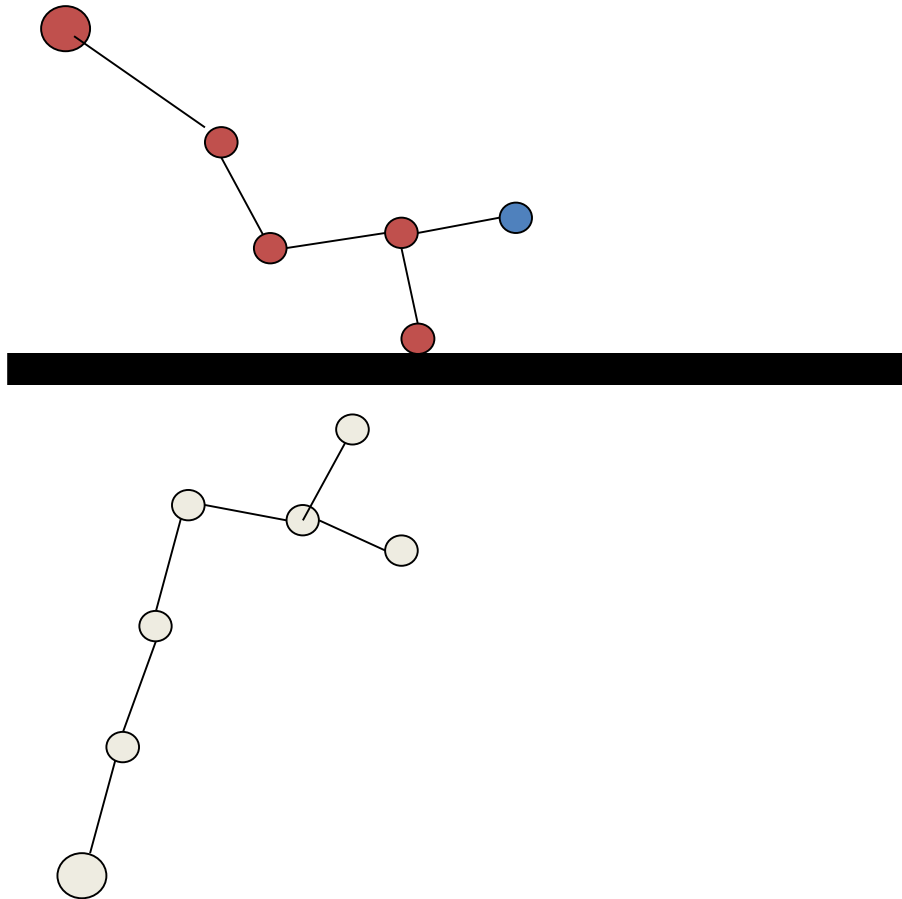


RRT-Connect: exemple

Phase croissance de l'arbre

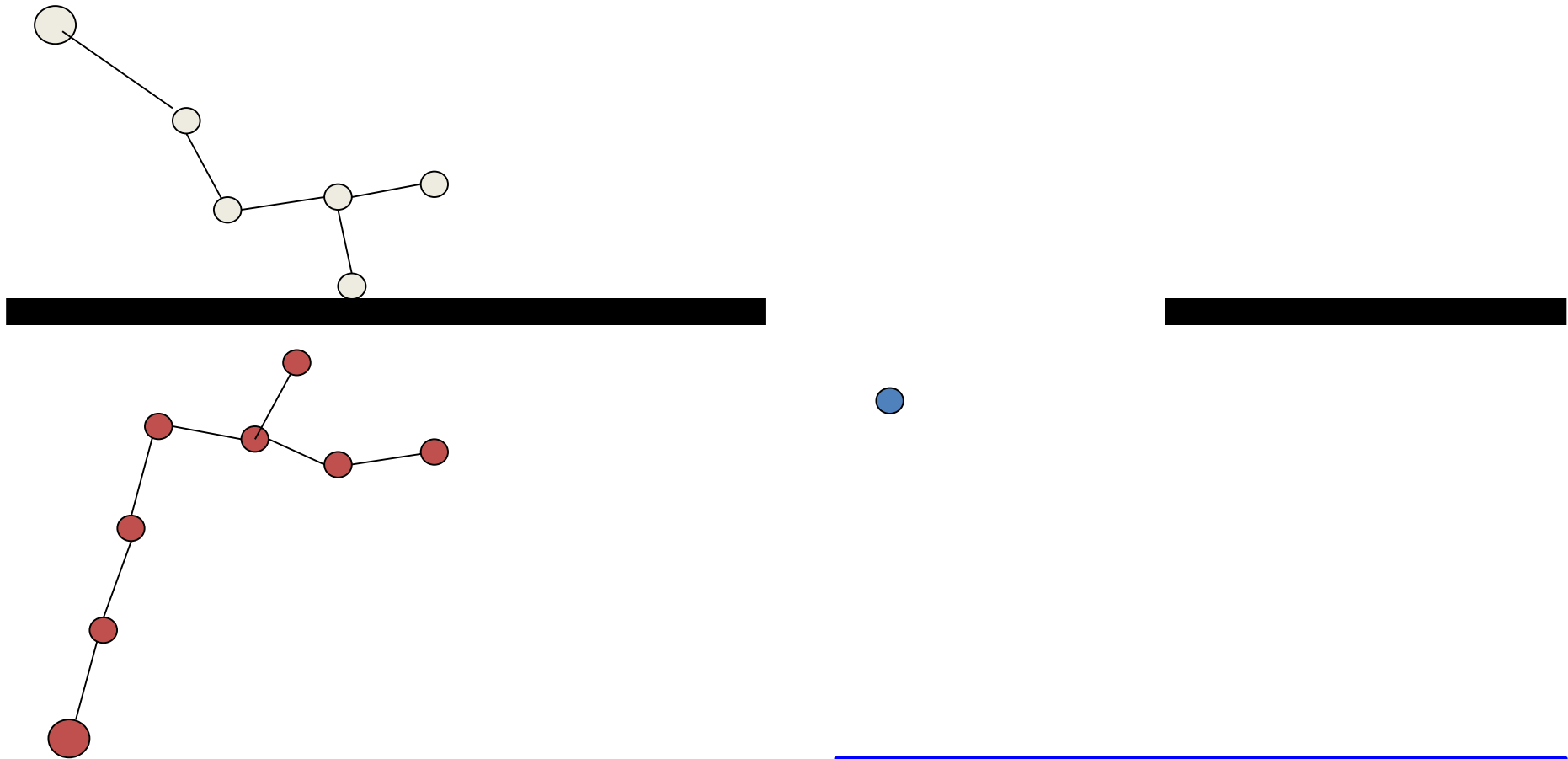


RRT-Connect: exemple



Phase connexion des arbres

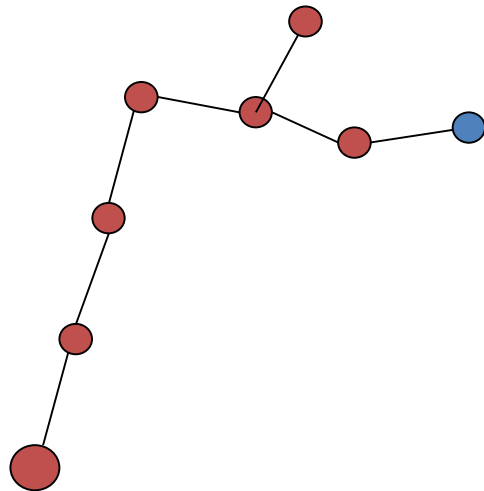
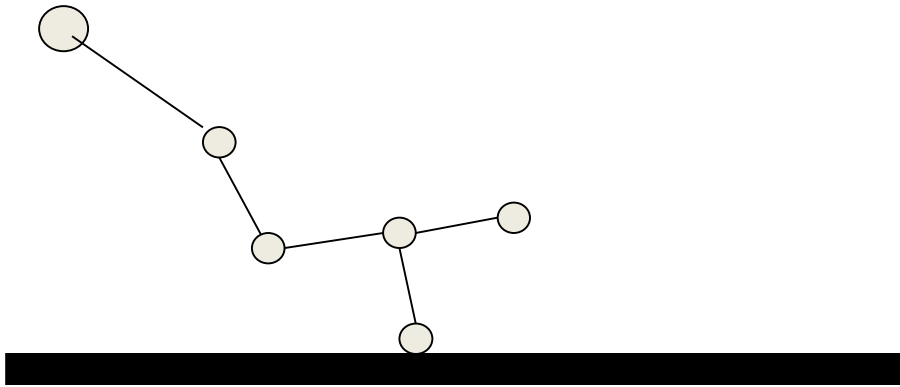
RRT-Connect: exemple



Phase croissance de l'arbre

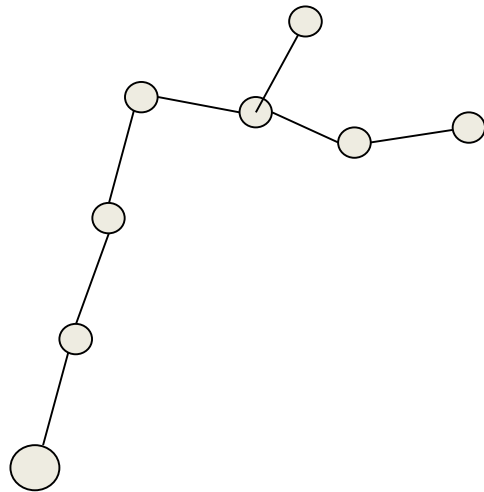
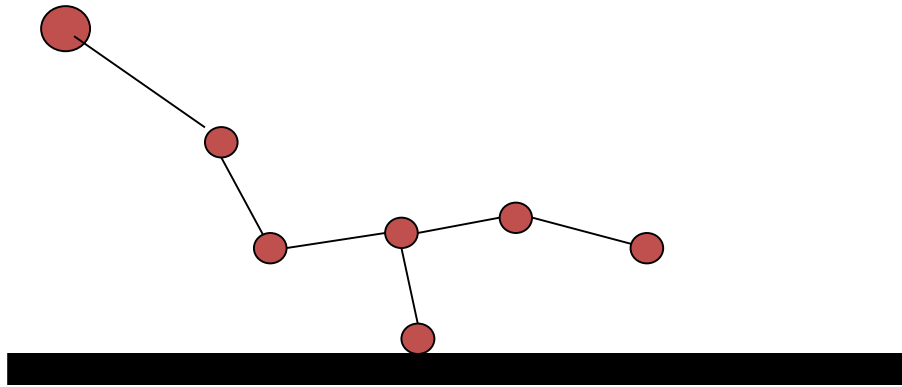
RRT-Connect: exemple

Phase connexion des arbres

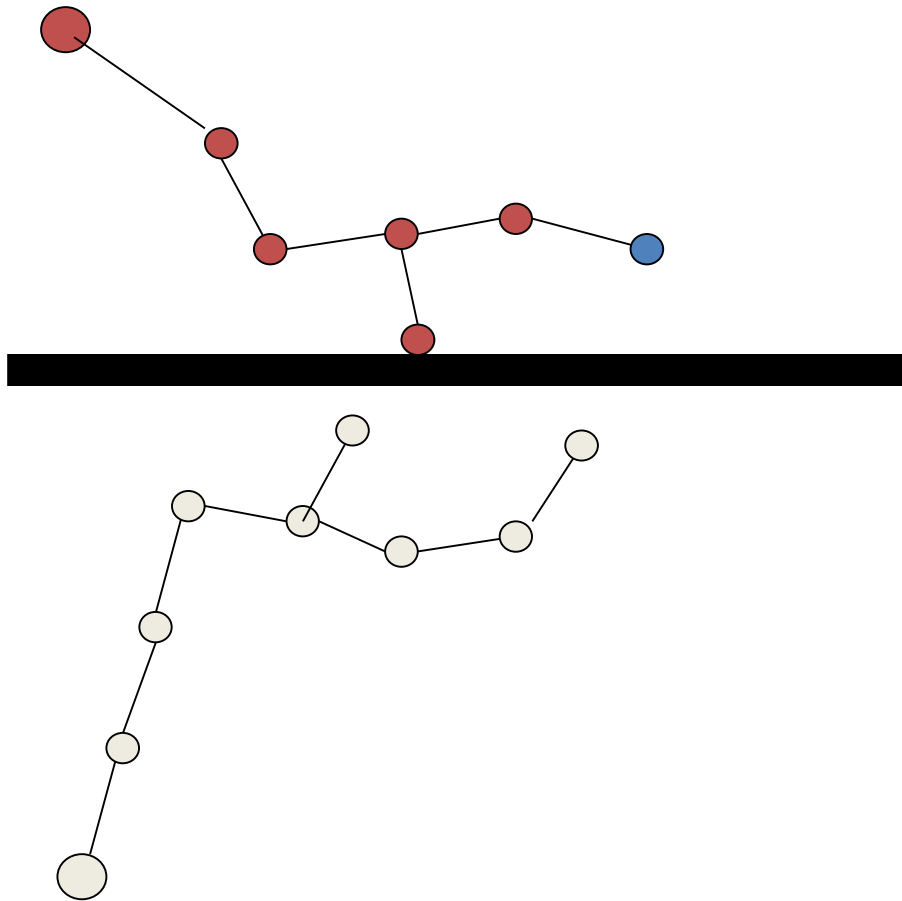


RRT-Connect: exemple

Phase croissance de l'arbre

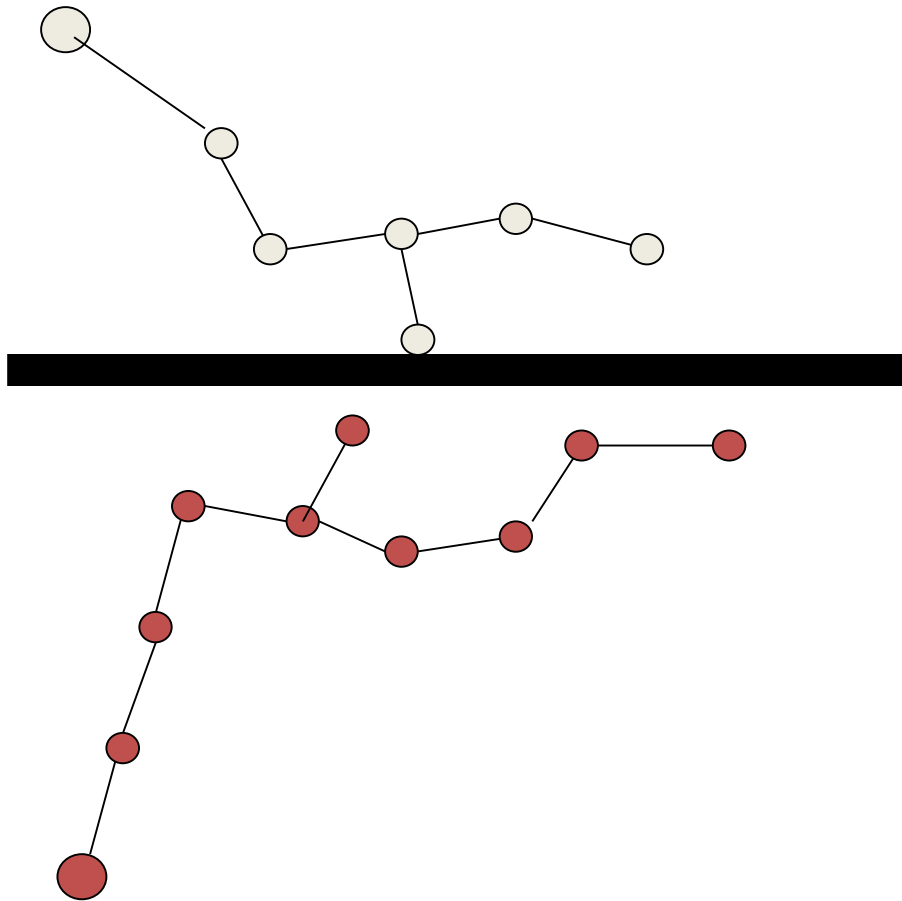


RRT-Connect: exemple



Phase connexion des arbres

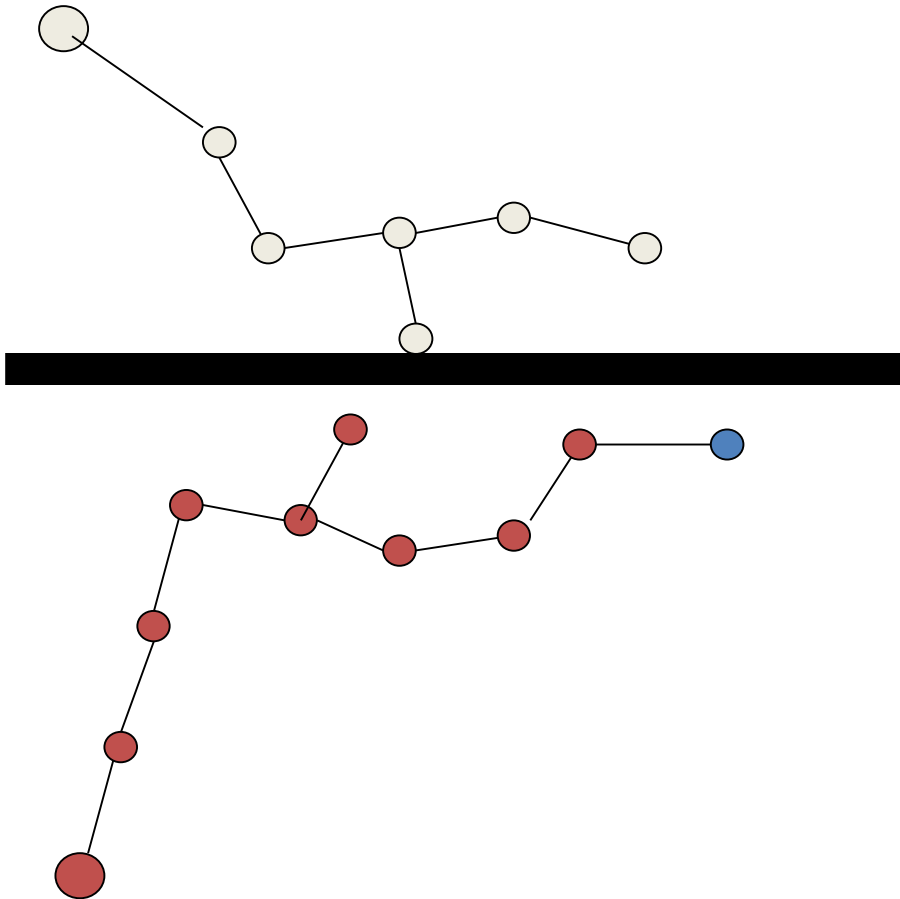
RRT-Connect: exemple



Phase croissance de l'arbre

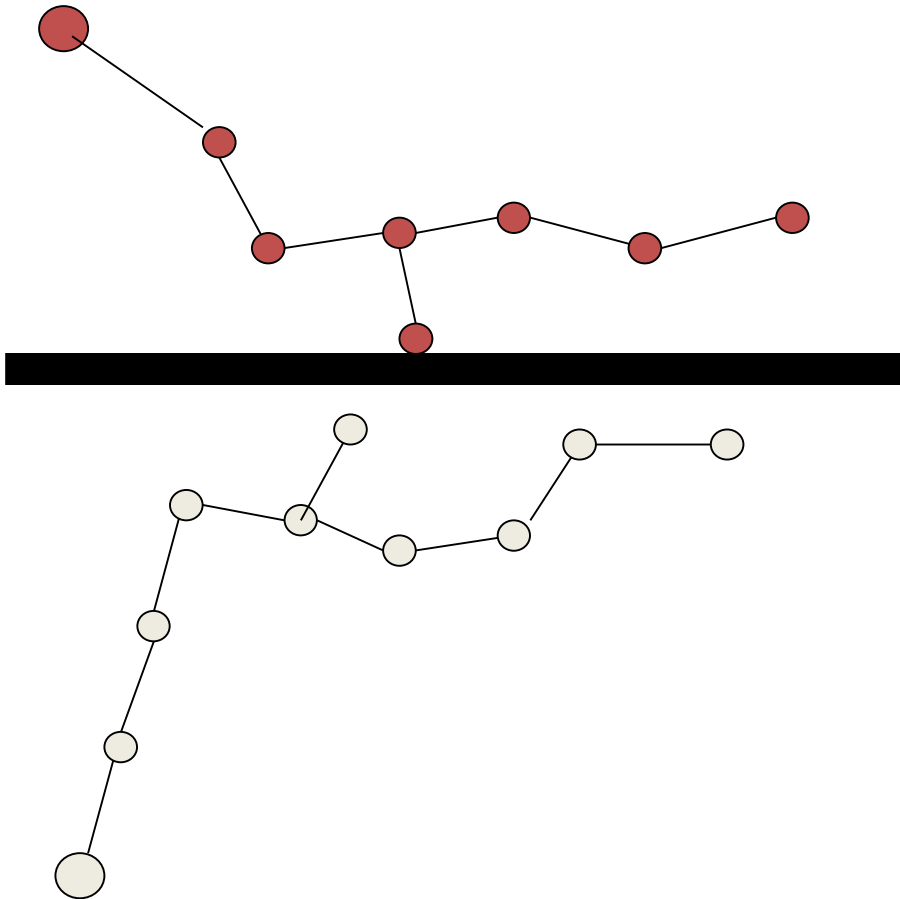
RRT-Connect: exemple

Phase connexion des arbres

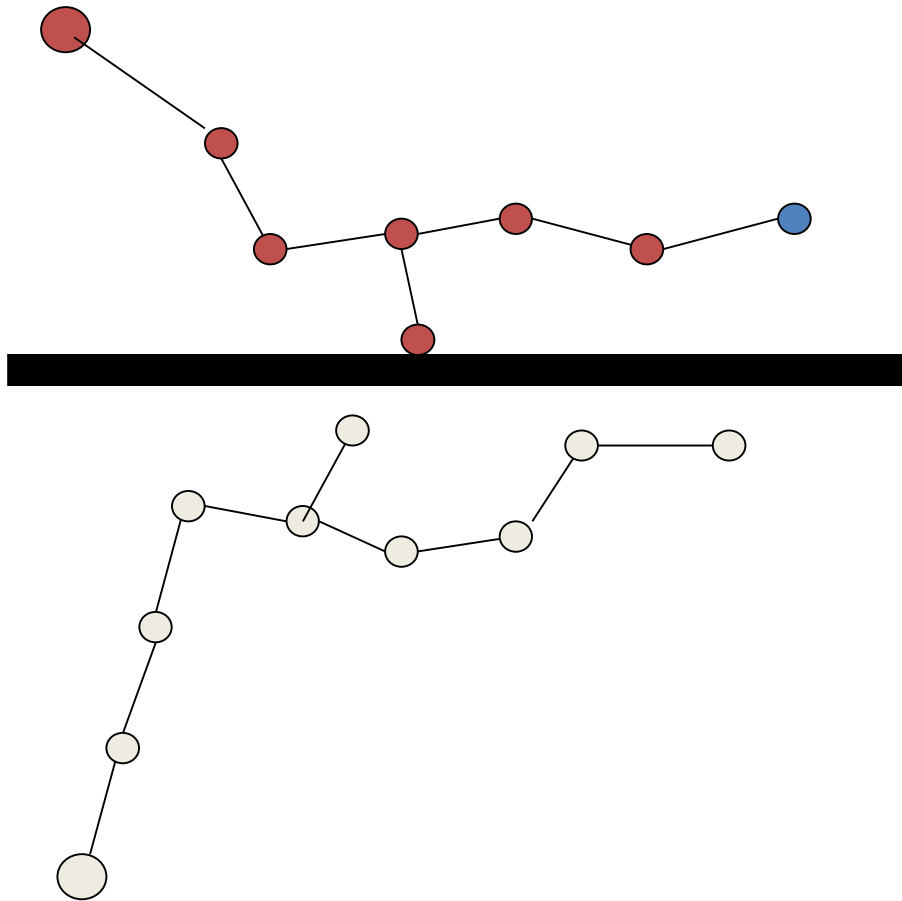


RRT-Connect: exemple

Phase croissance de l'arbre

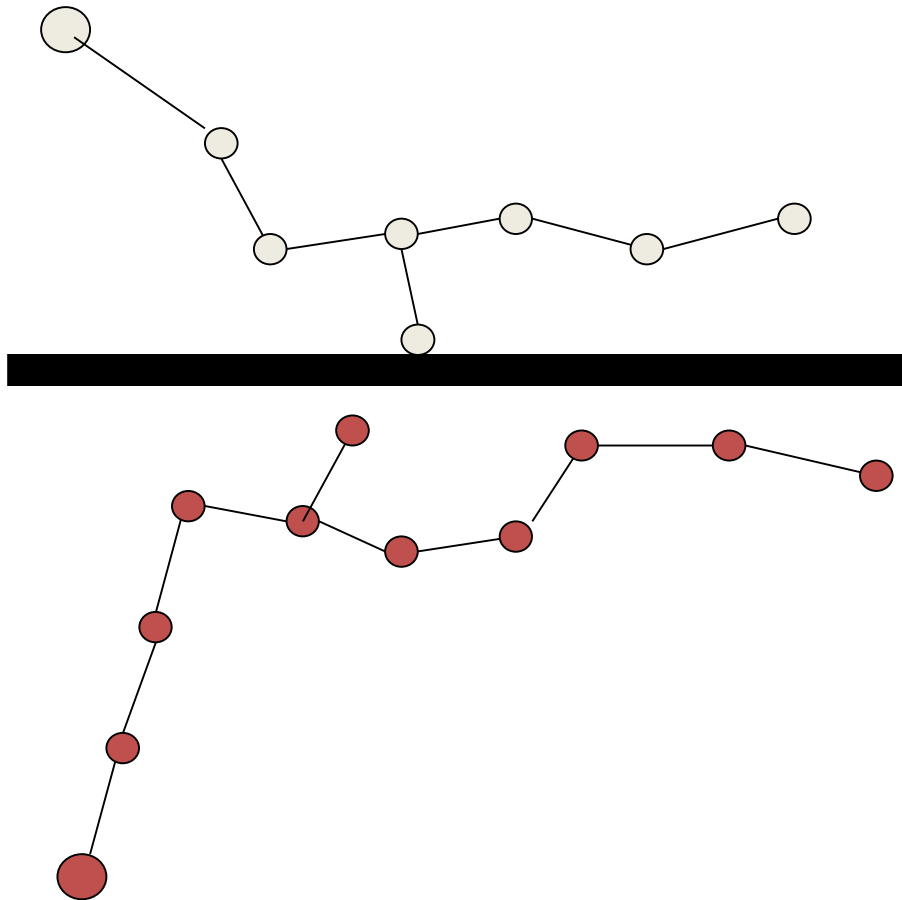


RRT-Connect: exemple



Phase connexion des arbres

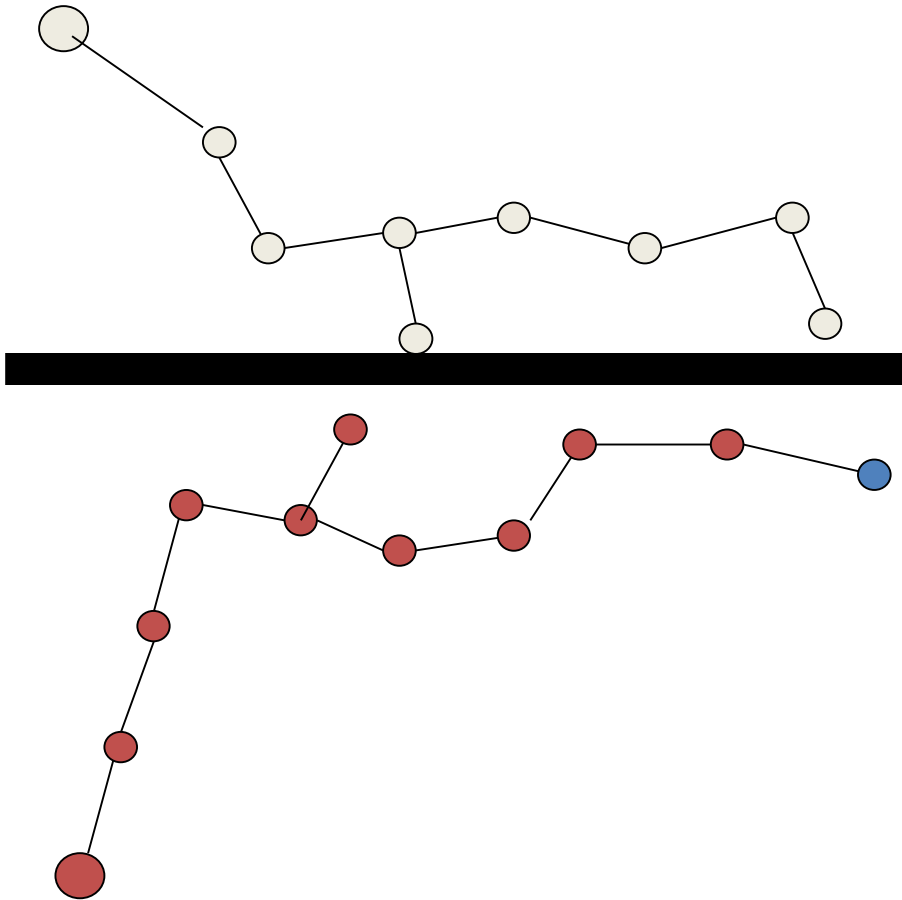
RRT-Connect: exemple



Phase croissance de l'arbre

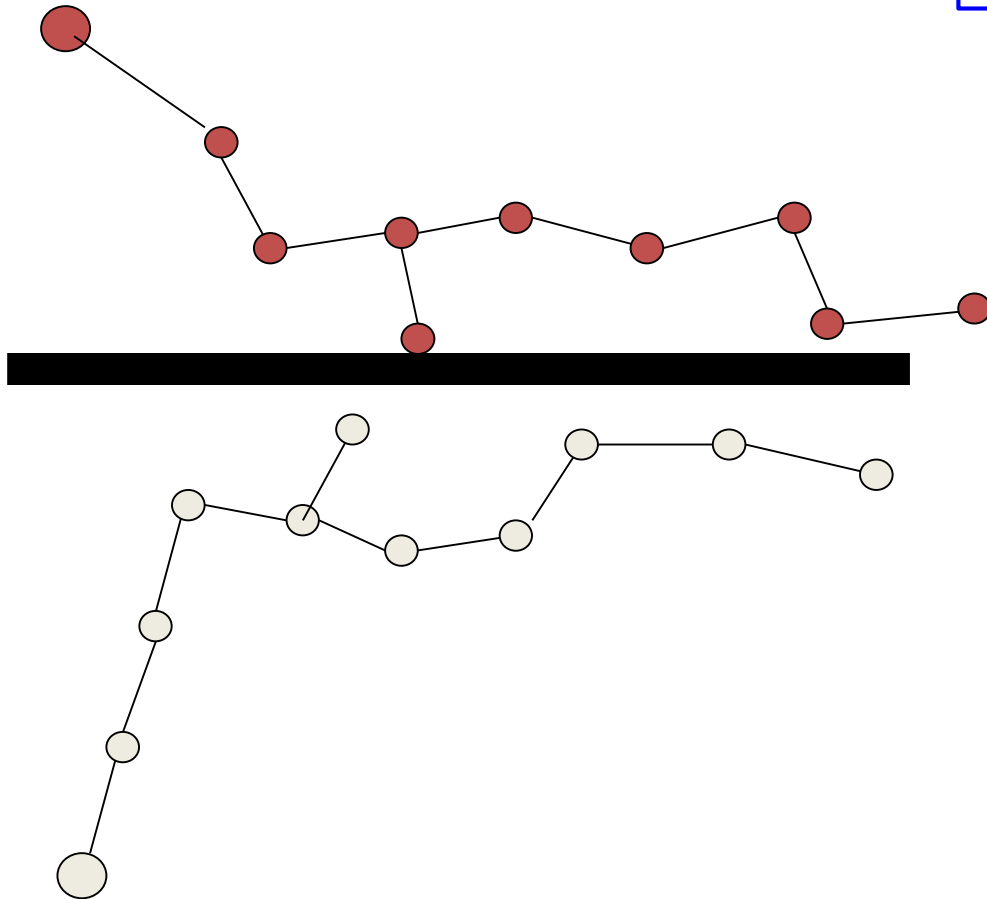
RRT-Connect: exemple

Phase connexion des arbres

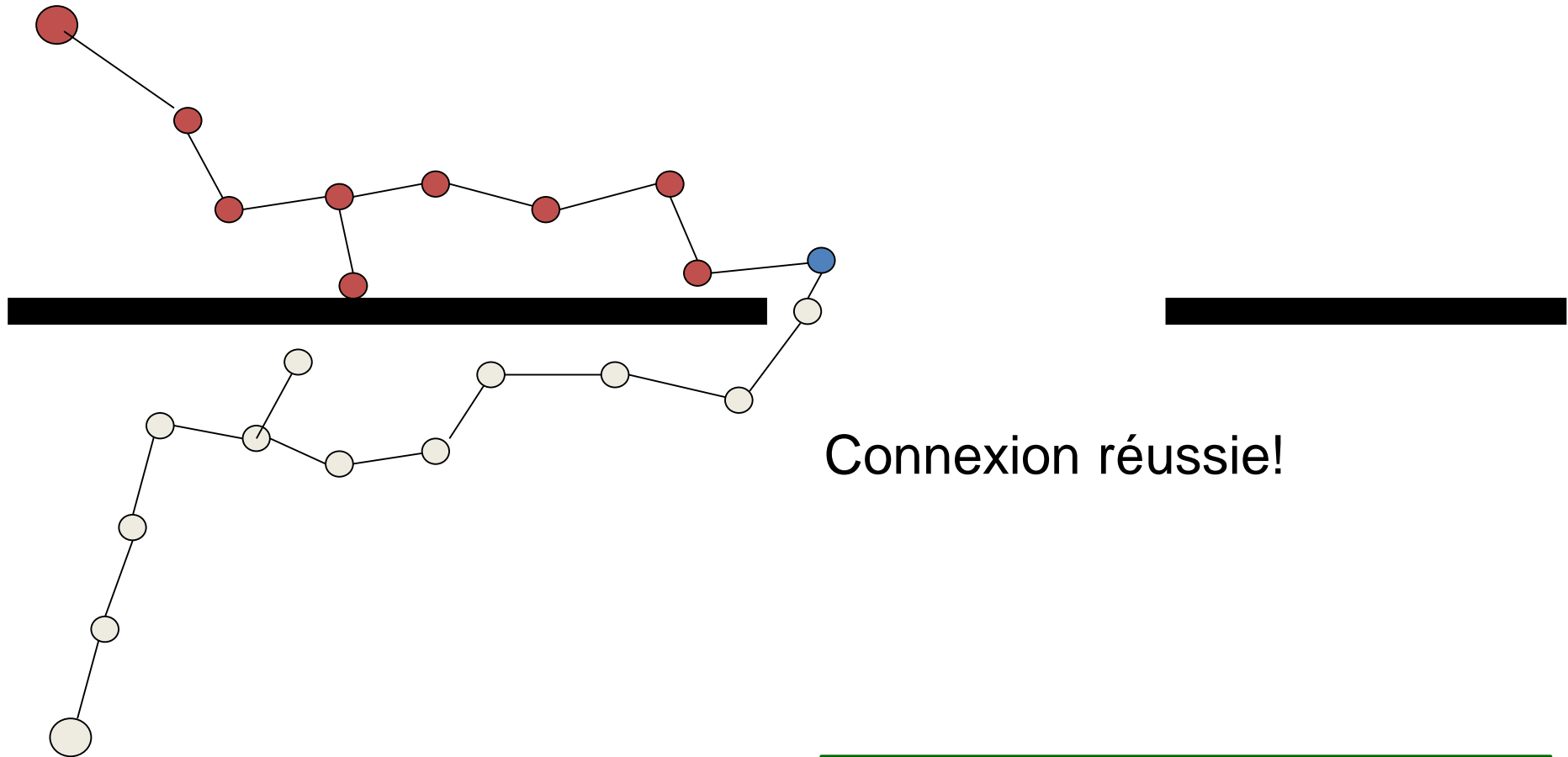


RRT-Connect: exemple

Phase croissance de l'arbre

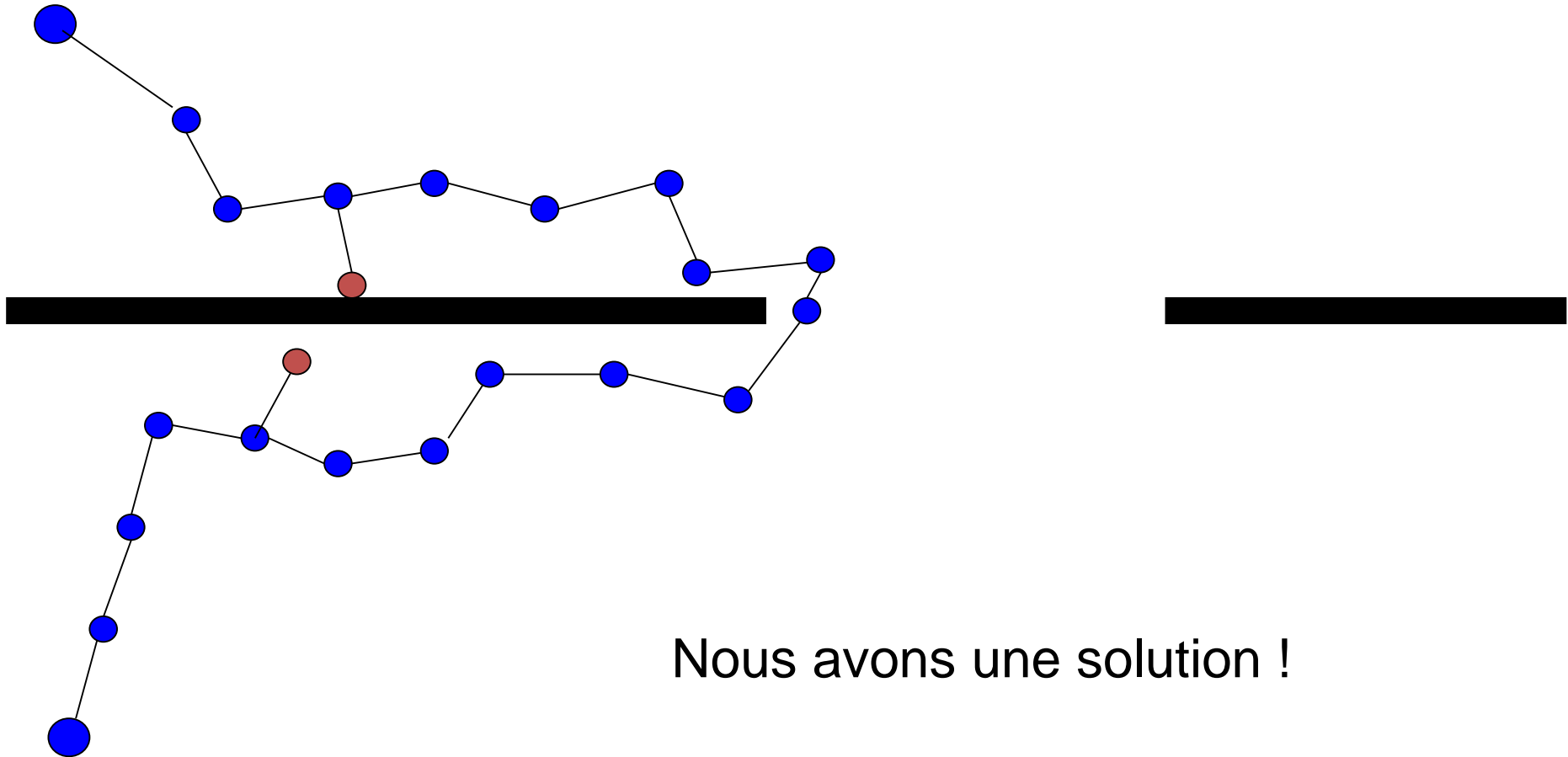


RRT-Connect: exemple



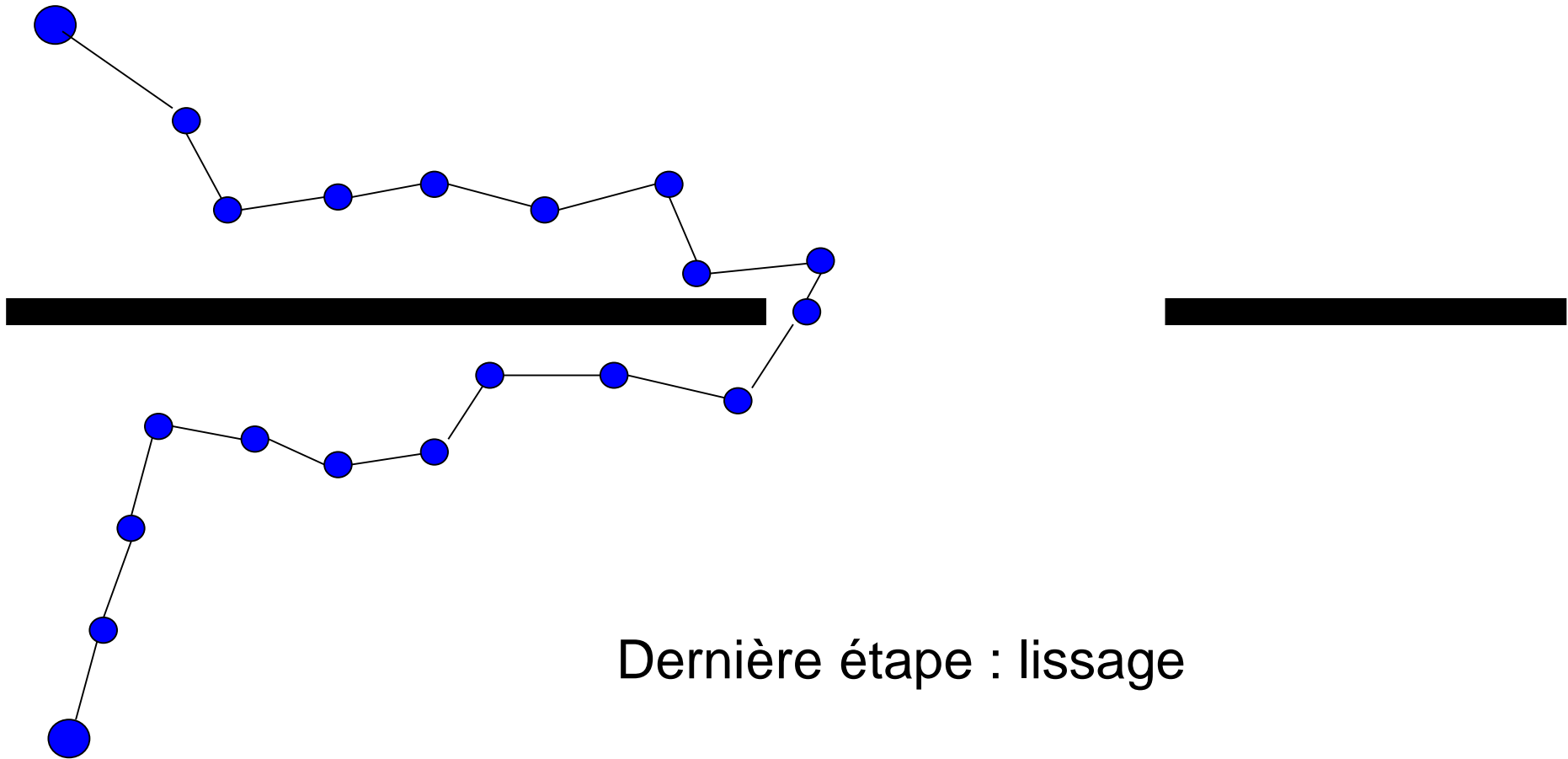
Phase connexion des arbres

RRT-Connect: exemple



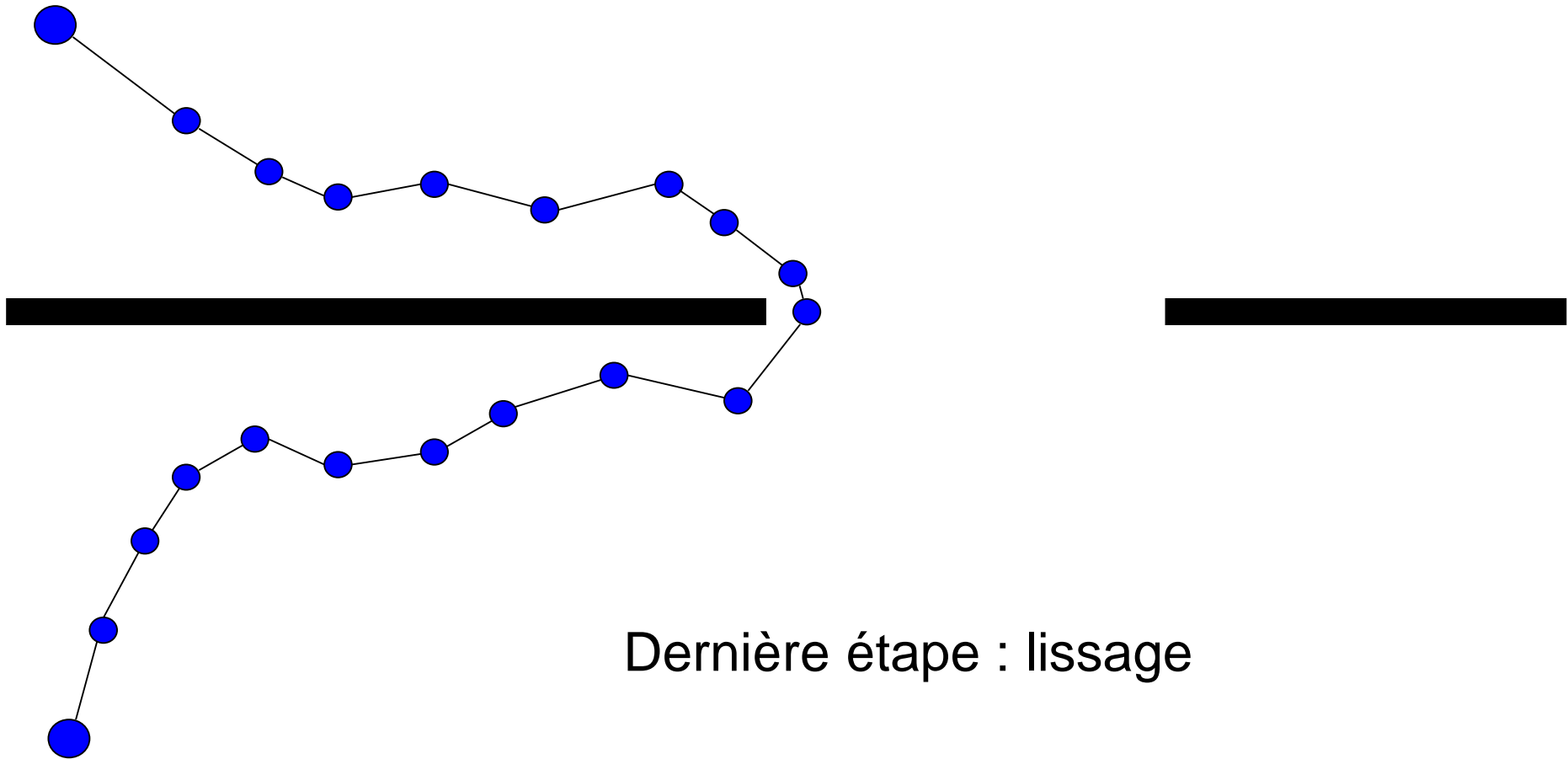
Nous avons une solution !

RRT-Connect: exemple



Dernière étape : lissage

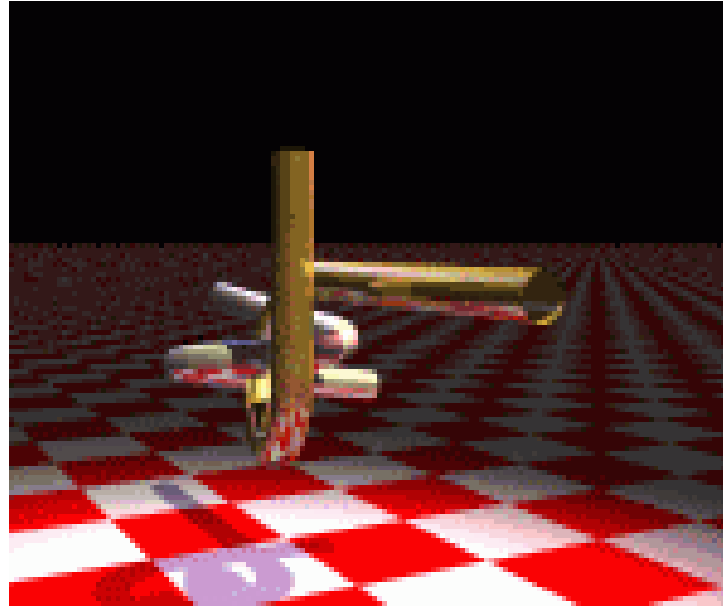
RRT-Connect: exemple



Dernière étape : lissage

Exemple de problème résolu avec RRT

- Extractions de deux tiges courbées



Problème proposé par Boris Yamrom, GE comme exemple de problème difficile. Repris par Nancy Amato, Texas A&M University. Solution en 2001 par James Kuffner et Steve LaValle. Calcul sur un PC de 2003 : quelques minutes.

RRT-Connect si non-holonome

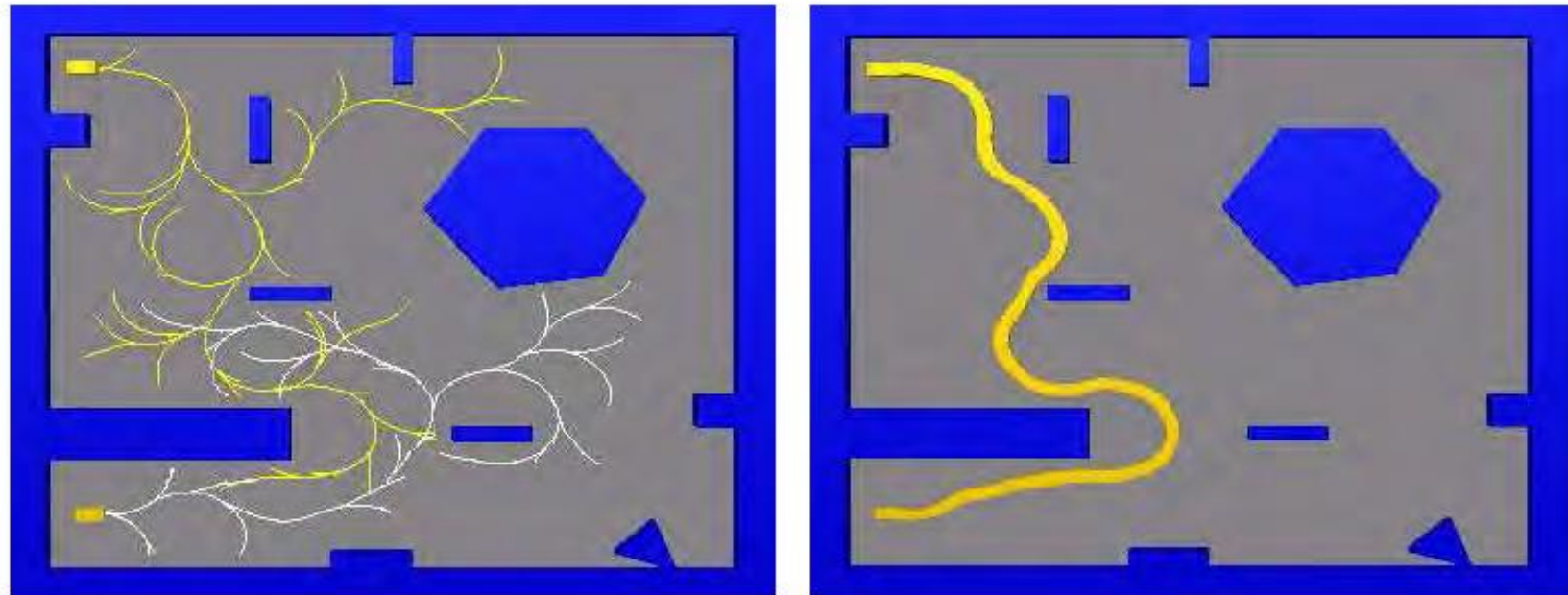


Fig. 4. The RRT obtained with a bidirectional planner (RRT-ExtExt) in 22.583 secs and 1376 nodes.

Exploring unknown environments with RRT-based strategies

Abraham Sánchez L. and René Zapata