



Disjoint Splitting for Multi-Agent Path Finding with Conflict-Based Search

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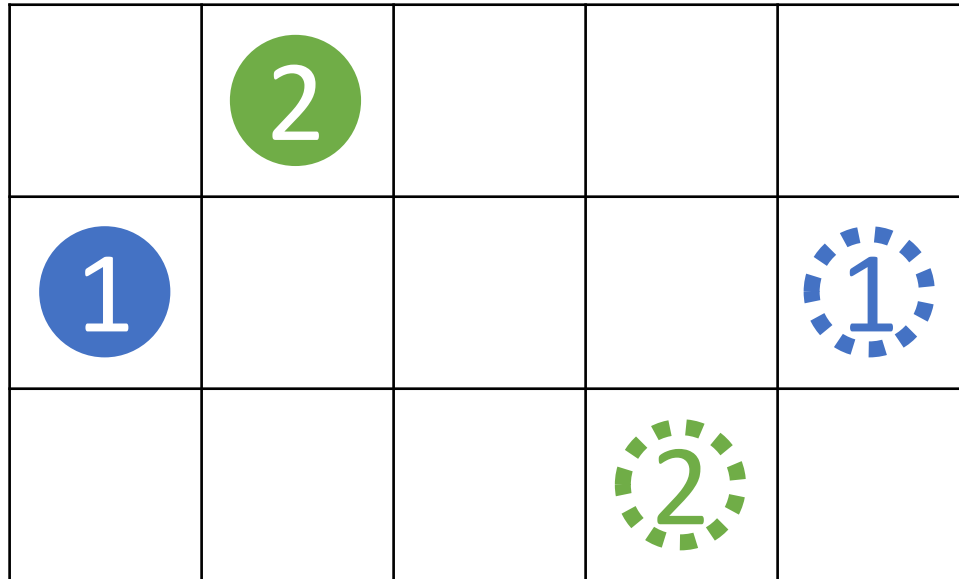


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Multi-Agent Path Finding (MAPF)

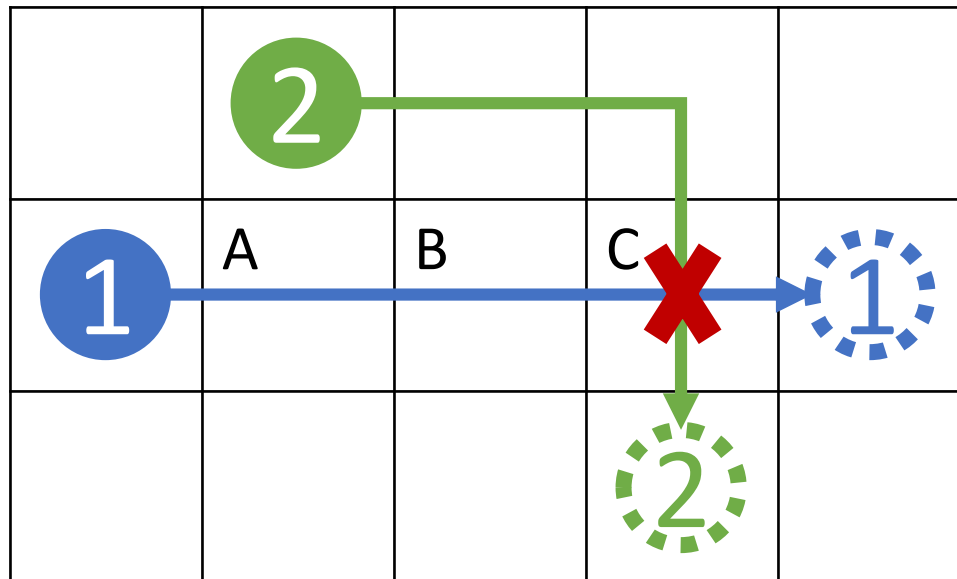


- Goal:
 - Find collision-free paths.
 - Minimize the sum of path costs.
- MAPF is NP-hard to solve optimally.

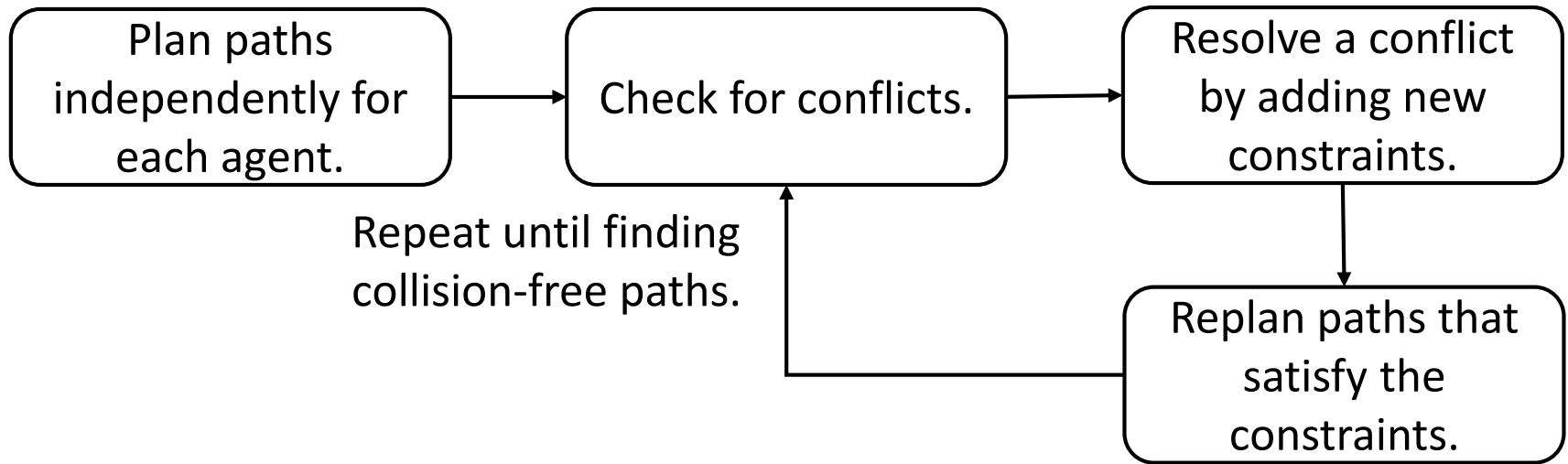
Conflict-Based Search (CBS)



Both agents are at C at time 3.

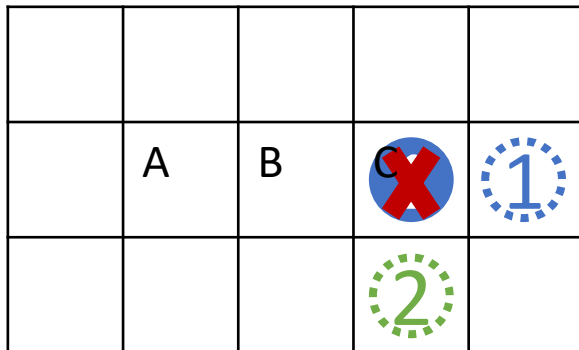


Conflict-Based Search (CBS)



Case 1:

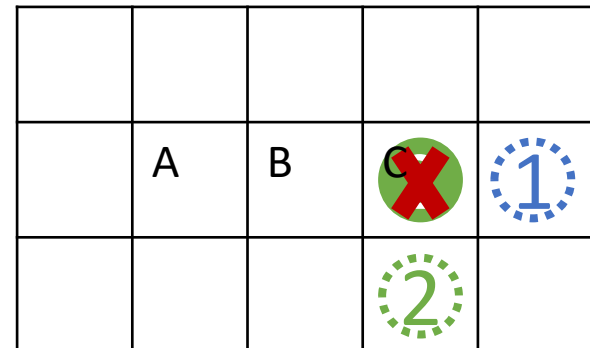
Agent 1 cannot be at C at time 3.



Case 2:

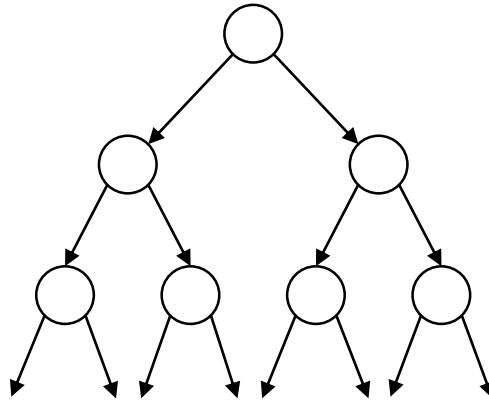
Agent 2 cannot be at C at time 3.

OR



Conflict-Based Search (CBS)

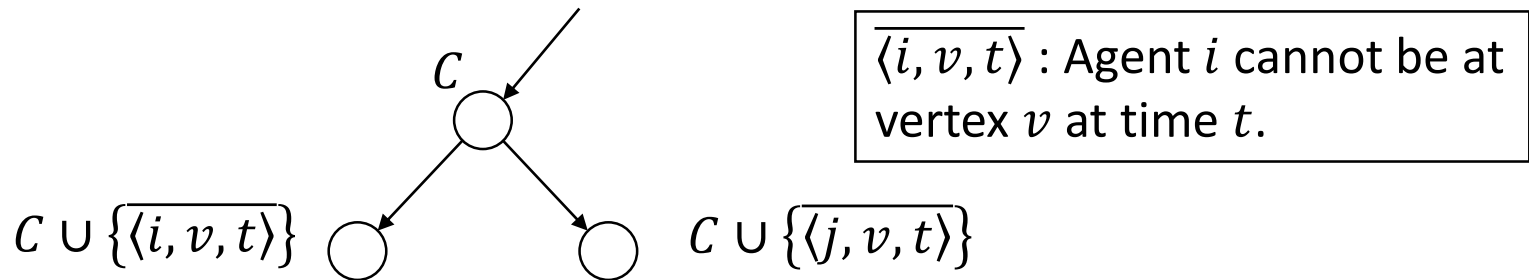
- The high-level of CBS searches in a binary tree using a best-first manner.



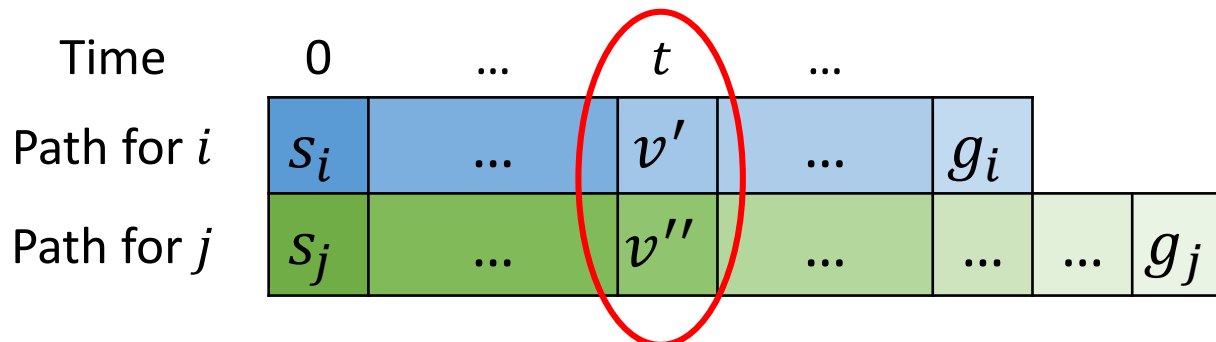
- The low-level of CBS replans paths for single agents.

The splitting of CBS

- To resolve a conflict between agents i and j at vertex v at time t :

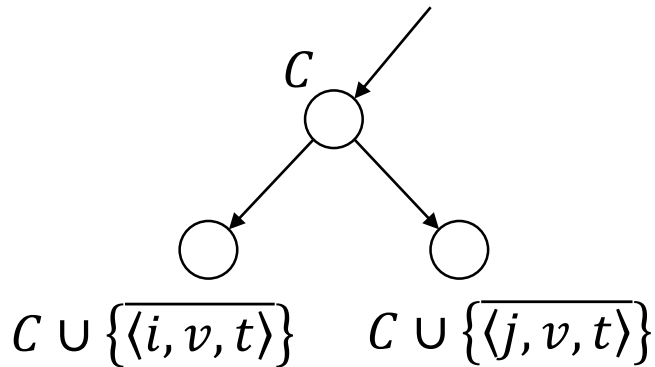


- The searching spaces (i.e., sets of paths that satisfy the constraints) of the two child nodes are **not disjoint!**
 - The following pair of paths satisfies both constraints.



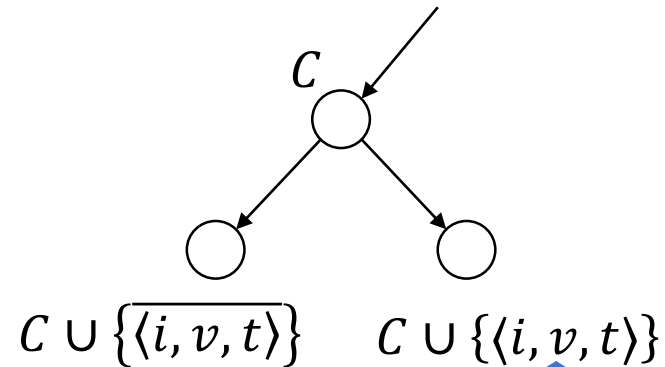
The splitting of CBS

- Non-disjoint splitting:



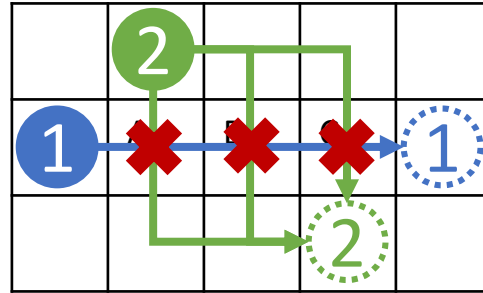
- Negative constraint $\overline{\langle i, v, t \rangle}$:
 - Agent i cannot be at v at time t .

- Disjoint splitting:

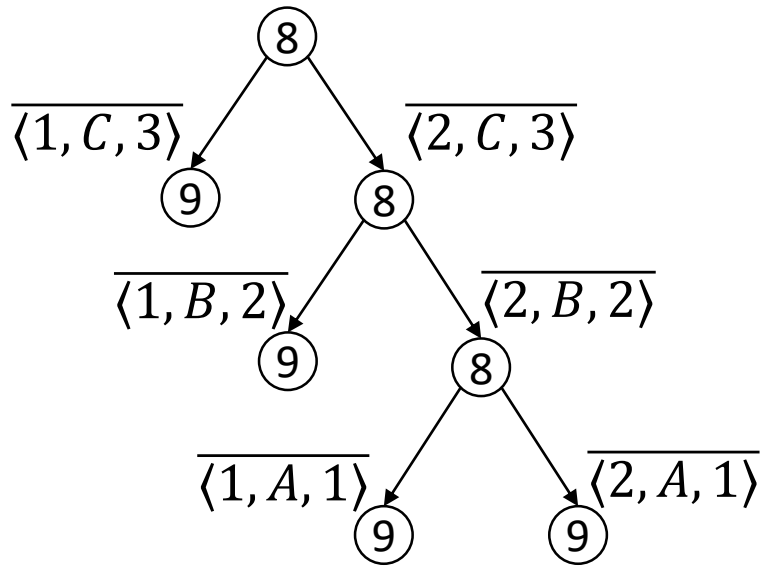


- **Positive constraint** $\langle i, v, t \rangle$:
 - Agent i must be at v at time t .
 - Any other agents (including agent j) cannot be at v at time t .

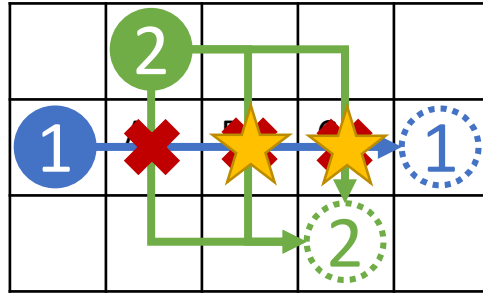
Example



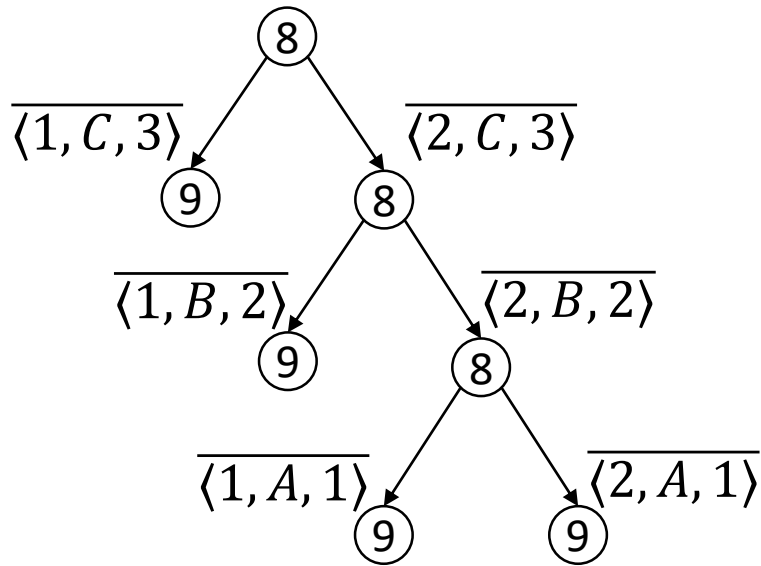
- Non-disjoint splitting:



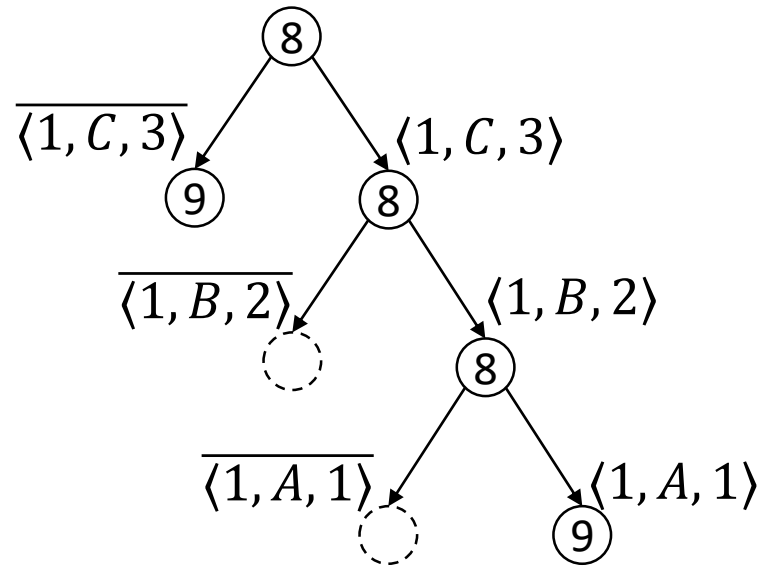
Example



- Non-disjoint splitting:



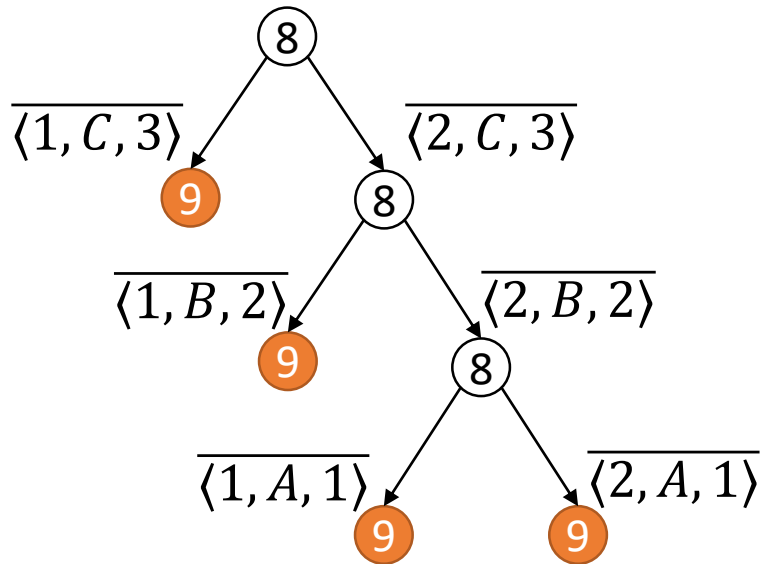
- Disjoint splitting:



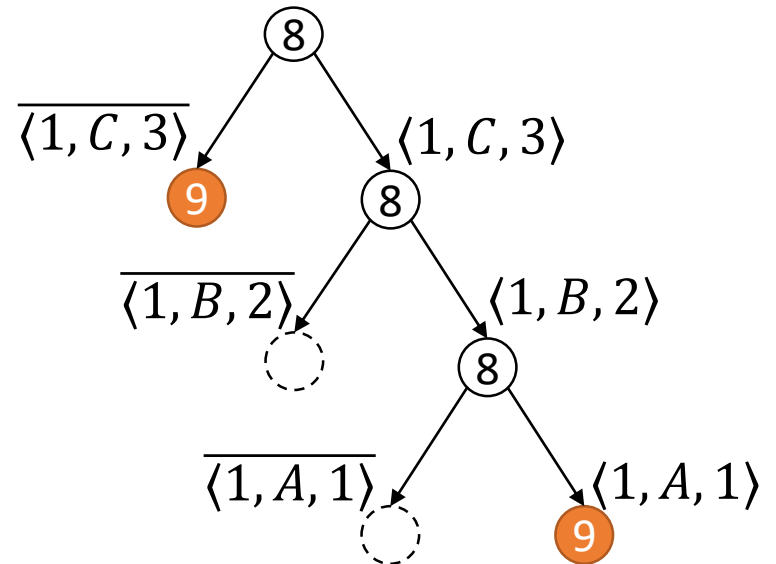
Example

	2			
1	A	B	C	1
			2	

- Non-disjoint splitting:



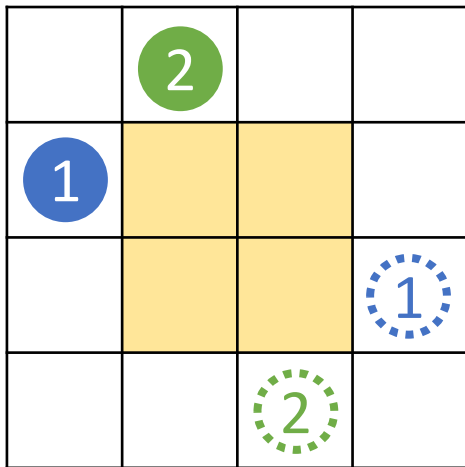
- Disjoint splitting:



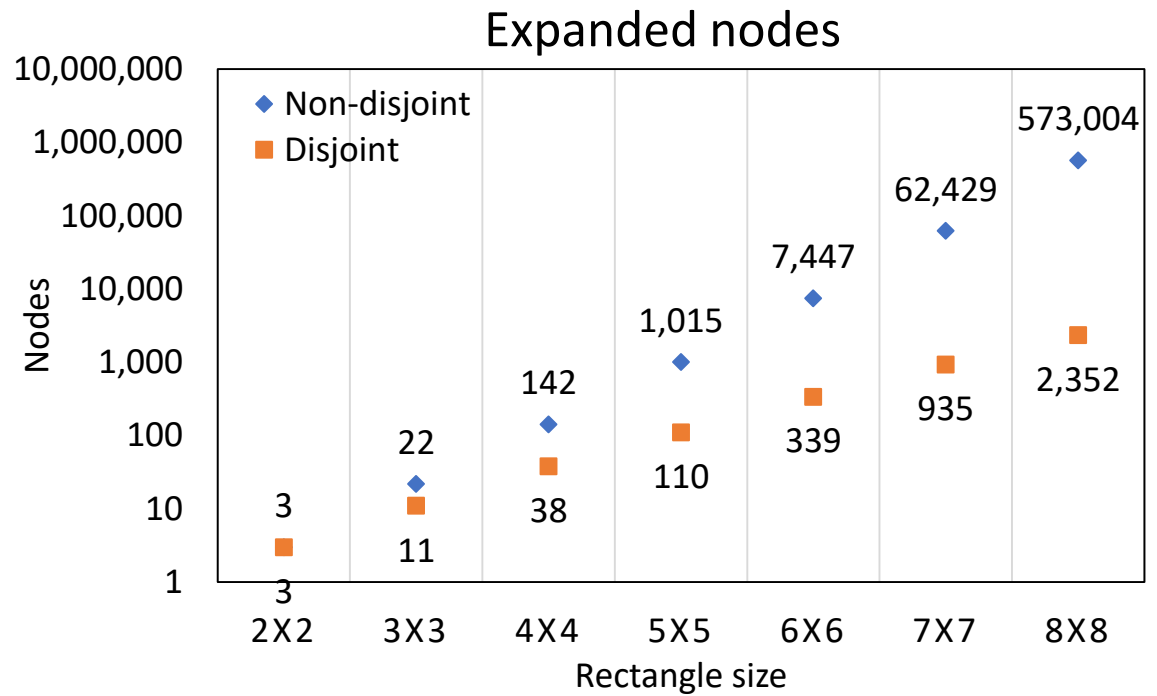
Low-level search of CBS

- Non-disjoint splitting
 - Replan the entire path.
- Disjoint splitting
 - Replan the path segment between two positive constraints.

Experiments



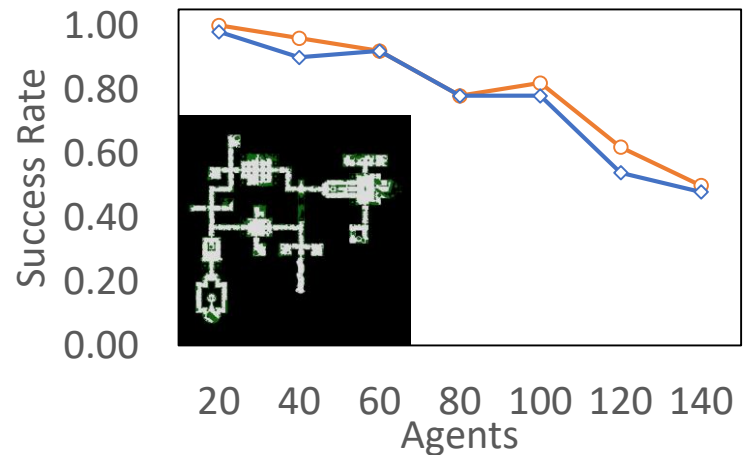
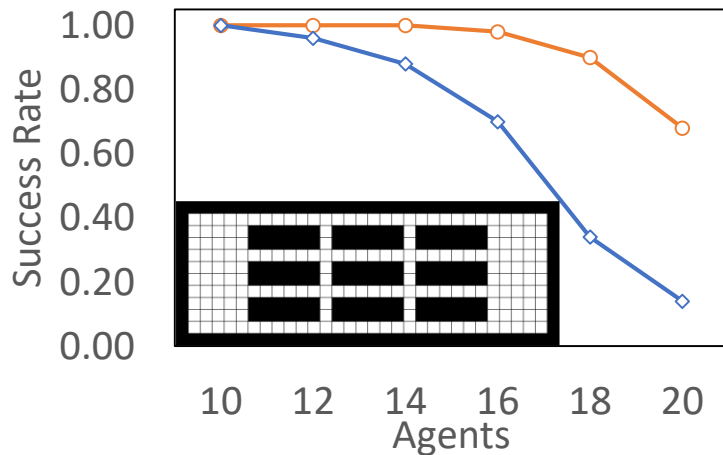
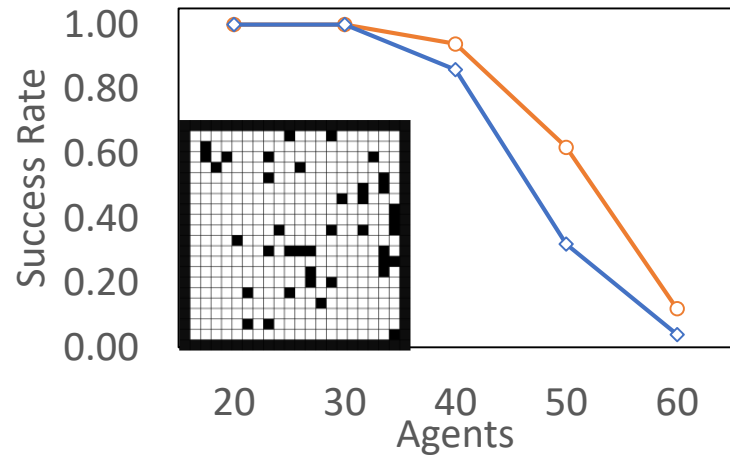
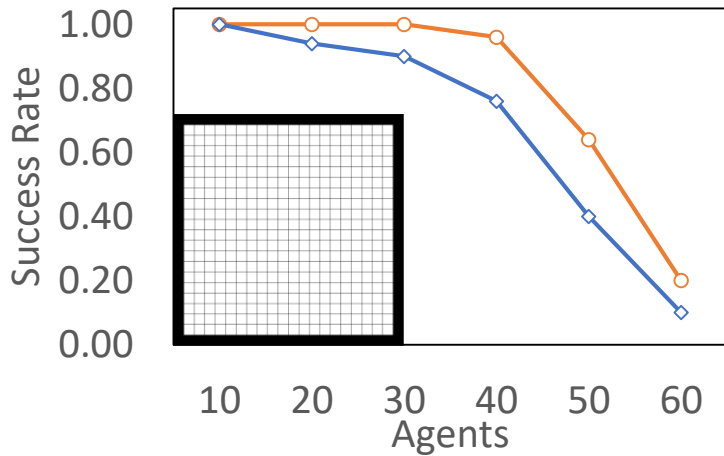
2x2 rectangle conflict



Experiments

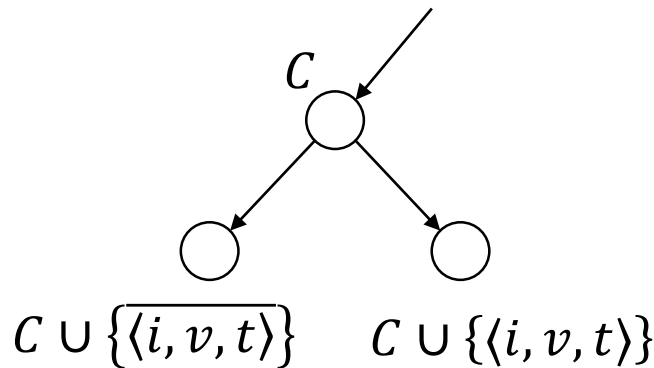
Success rate (%solved instances within 5 minutes)

—○— Disjoint —◇— Non-disjoint



Takeaways

- The splitting of standard CBS is not disjoint.
- Disjoint splitting:



Positive constraint:

- Agent i must be at v at time t .
- Any other agents cannot be at v at time t .

- Empirically, disjoint splitting is at least as good as CBS splitting and significantly speeds up CBS in many cases.