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**AE3M33MKR
Multi-robot Path Coordination
WHCA***

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There is a group of robots moving in 2D environment with few narrow passages. Coordinate the movement of all robots, that there will be no collisions and there will be no dead-lock. The shared resource is in this case the space.

Implement path planning algorithm, that

- ▶ plan the collision-free path for n-robots**
- ▶ avoid the deadlocks (no indefinite waiting) - report there is no solution**
- ▶ plan on arbitrary map (occupancy grid format)**



Windowed hierarchical coordinated A* [1]

- ▶ Decoupled approach - plan separately for each robot**
- ▶ On-line planner - interleave computation and physical moves**
- ▶ Improved heuristic - use Reverse Resumable A* (RRA*)**
- ▶ Reuse search data in the abstract domain**
- ▶ Only reserves paths of length W**
- ▶ Different ordering of robots in each cycle**



Algorithm 1: WHCA*(O, G)

Data: MAP, W, K

reset τ ;

while *some robots are not at their goal* **do**

foreach *permutation(robot r_i)* **do**

 find Path(r_i, τ);

 Reserve first W steps;

foreach *robot r_i in parallel* **do**

 Move r_i K time steps;

 reset T;

τ is reservation table



Procedure Initialize RRA*(O, G)

G.g \leftarrow 0;

G.h \leftarrow MANHATTAN (G, O);

Open \leftarrow G;

Closed \leftarrow \emptyset ;

ResumeRRA*(O);



Procedure ResumeRRA*(N)

```
while  $Open \neq \emptyset$  do  
   $P \leftarrow pop(Open)$ ;  
   $Closed \xleftarrow{add} P$  ;  
  if  $P = N$  then  
    return success;  
  forall  $Q \in reverse(SUCCESSORS(P))$  do  
     $Q.g \leftarrow P.g + COST(P, Q)$ ;  
     $Q.h \leftarrow MANHATTAN(Q, \mathbf{O})$ ;  
    if  $Q \notin Open$  and  $Q \notin Closed$  then  
       $Open \xleftarrow{add} Q$   
    if  $Q \in Open$  and  $f(Q) < f(Q \in Open)$  then  
       $Open \xleftarrow{update} Q$   
return failure
```



Procedure heuristicDistance(N, G)

if $N \in \text{Closed}$ **then**

 | **return** $g(N)$;

if $\text{ResumeRRA}^*(N) = \text{success}$ **then**

 | **return** $g(N)$;

return ∞ ;

To reuse the heuristic computed by RRA^* , keep the Open and Close lists for each robot.



D. Silver, "Cooperative pathfinding," in *Proceedings of the First AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment, AIIDE'05*, p. 117–122, AAAI Press, 2005.