# Motion planning for hundreds of floating robots

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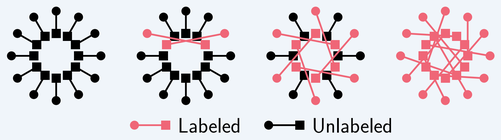
arXiv:2606.09620

## 1 Problem and initialization

We seek trajectories for $N$ planar robots between start and target configurations in $K$ time steps, satisfying the nonconvex collision constraint

$$\|p^{(i)}[k] - p^{(j)}[k]\|_2 \geq R \quad \text{for all } i \neq j,\ k. \tag{1}$$

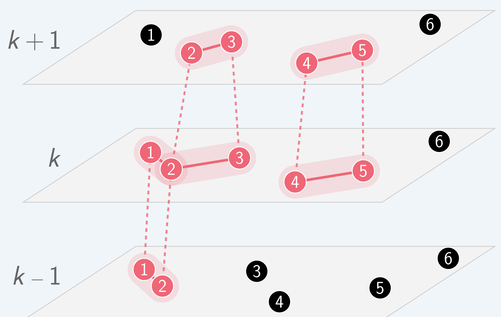
**Allocation.** Labeled robots get random fixed targets. Unlabeled robots are matched crossing-free in a linear assignment.




**Initialization.** Without (1), optimal paths are straight lines (above), with hundreds of collisions.

## 2 Collision graph

Which robots collide, and when?

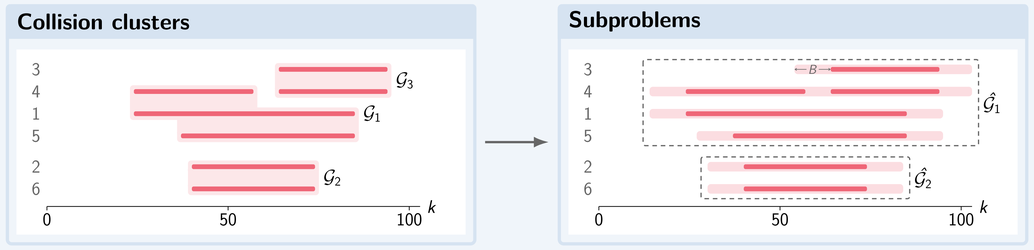



- **node:** robot $i$ at step $k$
- **spatial edge:** $i$ and $j$ collide at step $k$
- **temporal edge:** $i$ collides at steps $k$ and $k+1$

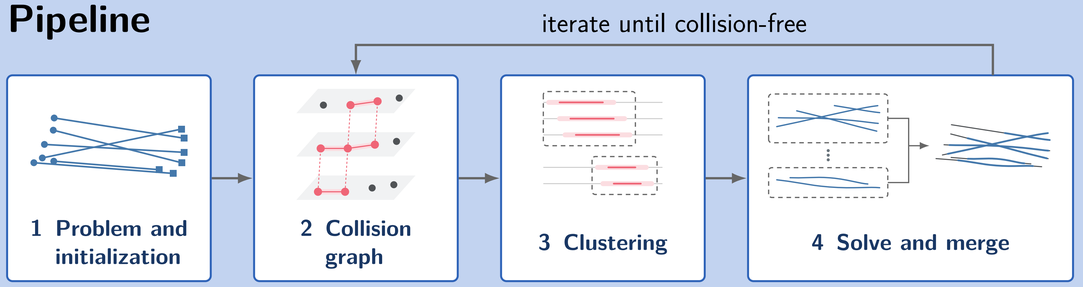
**Collision clusters** $\mathcal{G}_m$
connected components of the graph

## 3 Clustering

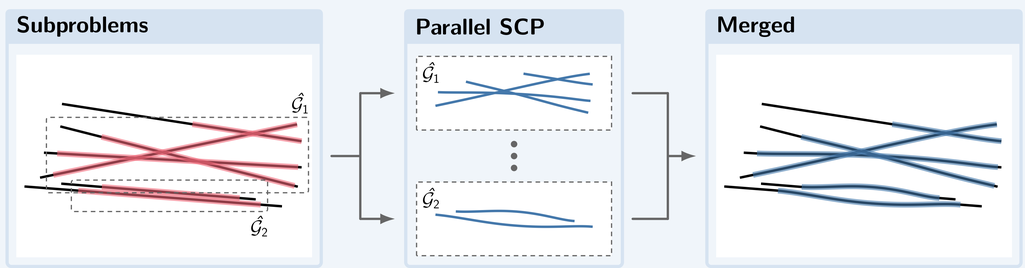
Turning collision clusters into subproblems




## Pipeline




## 4 Solve and merge

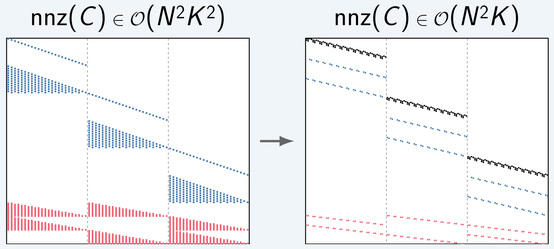



**SCP.** Iteratively solve

$$\min_{\chi} \ \|\chi\|_2^2 \quad \text{s.t.} \quad l \leq \begin{bmatrix} C_{\text{dyn}} \\ C_{\text{box}} \\ C_{\text{coll}} \end{bmatrix} \chi \leq u,$$

with $C_{\text{coll}}$ the collision constraint (1) linearized at the last iterate $\bar{p}$.

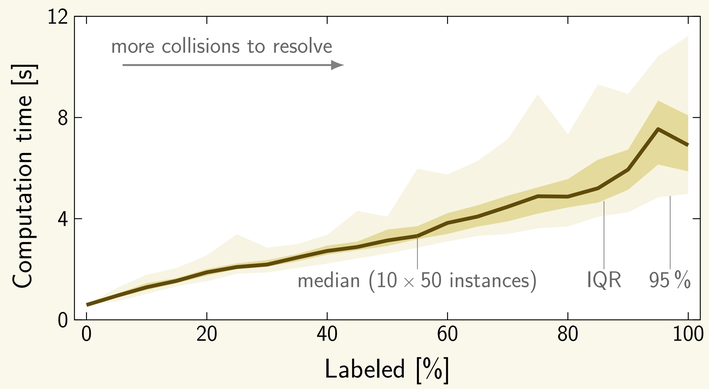
**Shooting** $\text{nnz}(C) \in \mathcal{O}(N^2K^2)$ → **Transcription** $\text{nnz}(C) \in \mathcal{O}(N^2K)$



## 5 Results: 500 robots in seconds

**Example transition:** *of* → ☆ ($N = 500$, $K = 1000$, 20 % labeled)






| | |
|---|---|
| 99 % | of instances resolved collision-free within 60 s |
| 3.1 s | median, 50 % labeled; monolithic SCP intractable |

## 6 Deployments

