The Any-Com Approach to Multi-Robot Coordination

Michael Otte and Nikolaus Correll, University of Colorado at Boulder

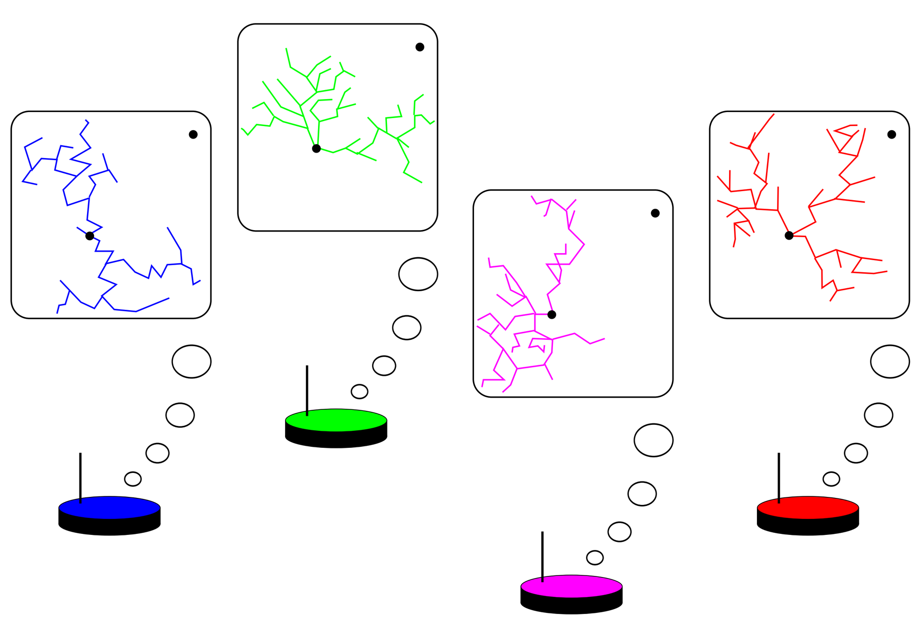
{michael.otte, nikolaus.correll}@colorado.edu

Overview

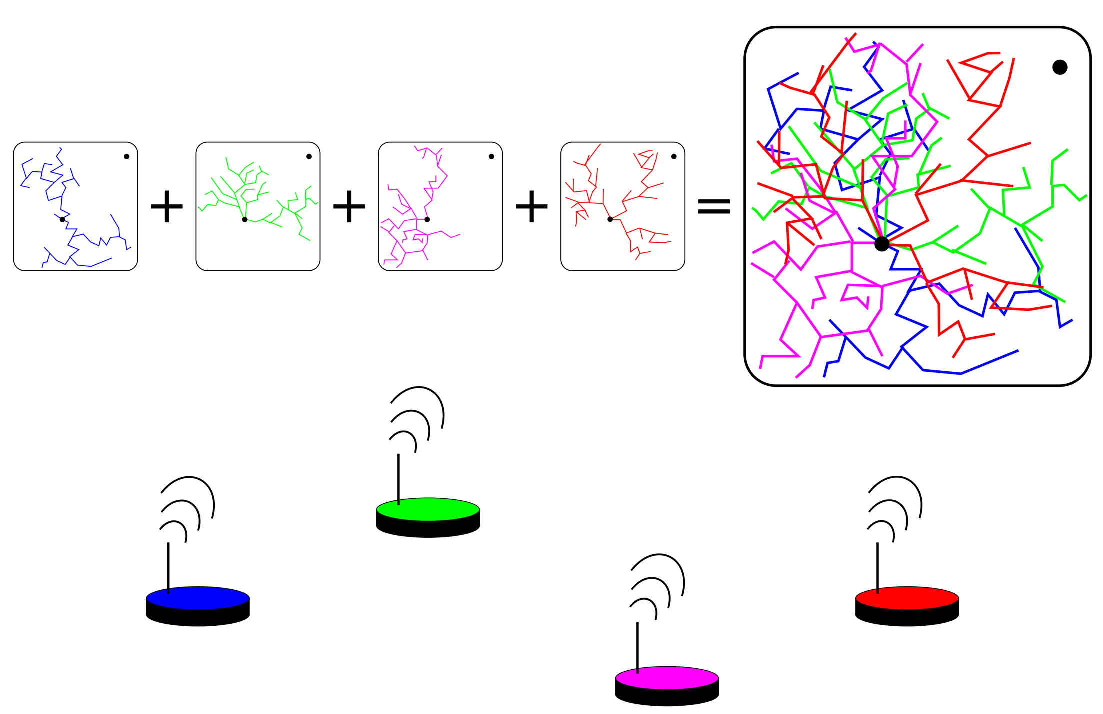
Multi-robot coordination algorithms that utilize available communication and are robust to communication failure.

- Find a suboptimal solution, refine as communication permits.
- Collaboration divides computational effort among n robots.
- Graceful performance decline relative to % packets dropped.
- Useful when less-expensive incomplete methods fail.

Distributed Random Tree

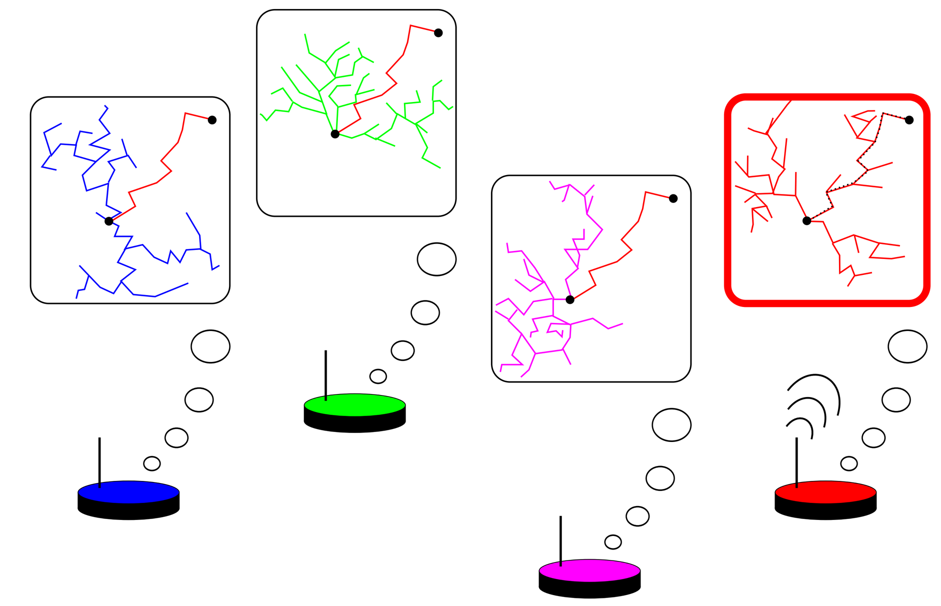


Each robots searches the configuration space using an any-time random tree.

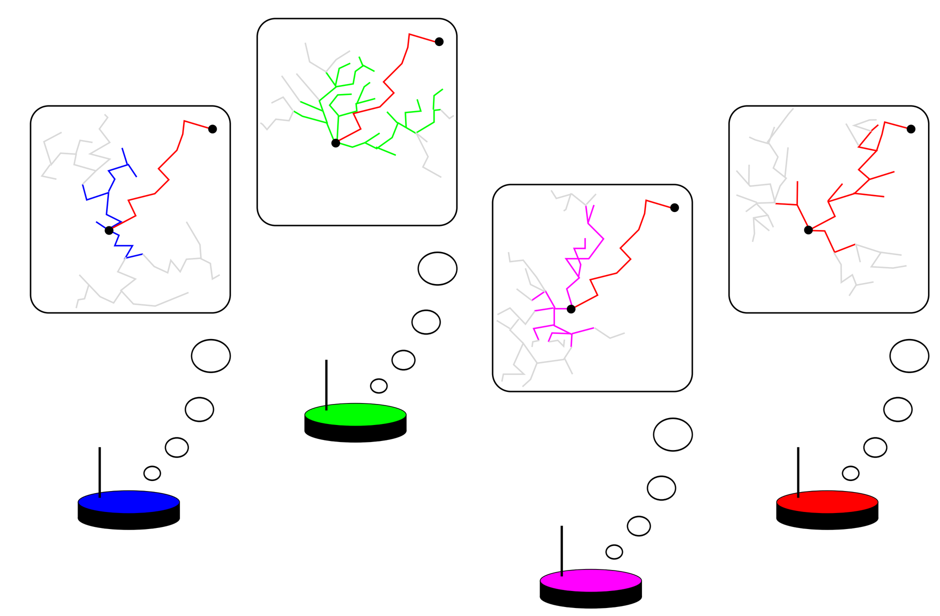


Union of all trees is itself a tree, $\mathcal{O}(n)$ times larger, that the team collectively explores.

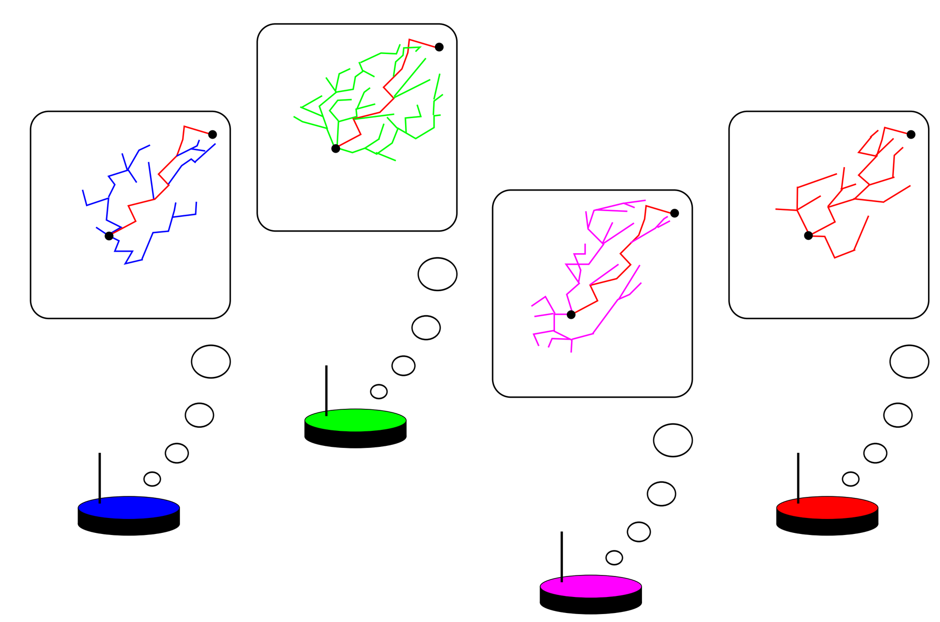
Partial Solution Sharing



Intermediate solutions are shared with the rest of the team as they are found.

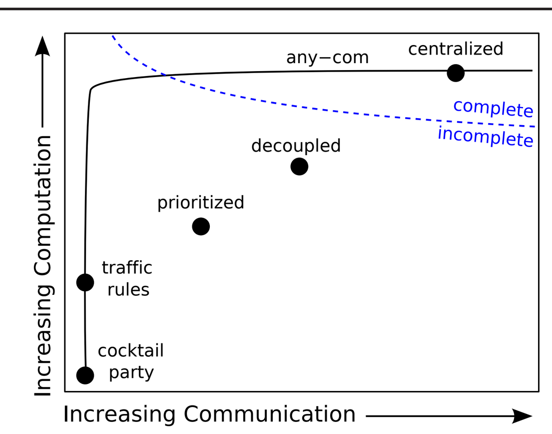


This allows each robot to prune its portion of the combined tree, focusing effort on finding even better solutions. Pruning is especially important in high dimensional C-spaces of multi-robot problems.



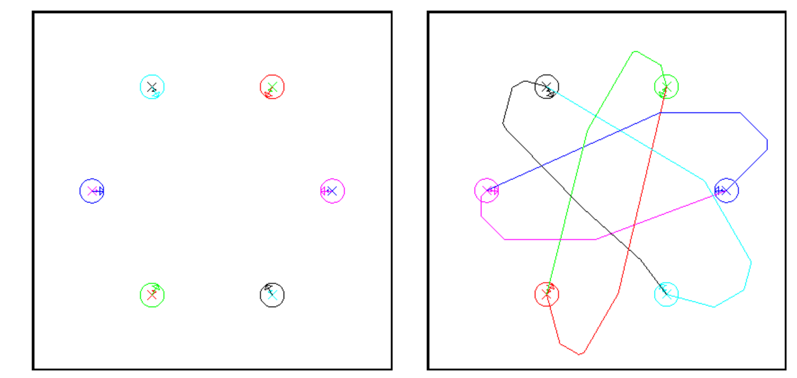
Partial solution sharing also lets all robots improve the best known solution.

Computational requirements and completeness vs. other methods:

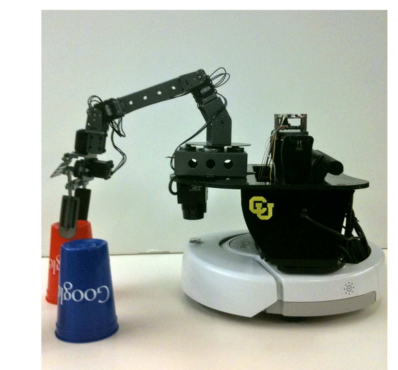


Example 1: Multi-Robot Navigation

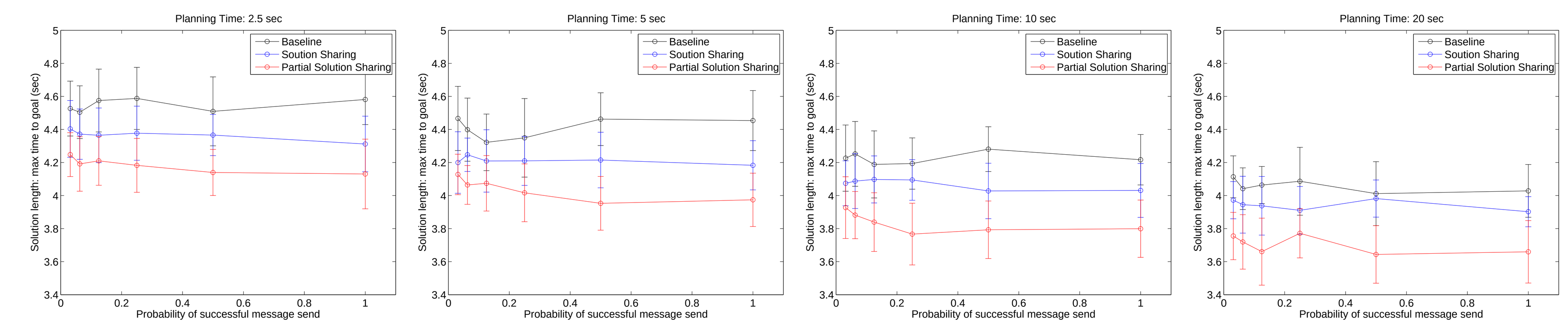
6 robots in both simulated and real environments. Evaluation vs. state of the art centralized algorithms: baseline (a server-client model) and solution sharing (each robot plans independently, and the team uses the best result).



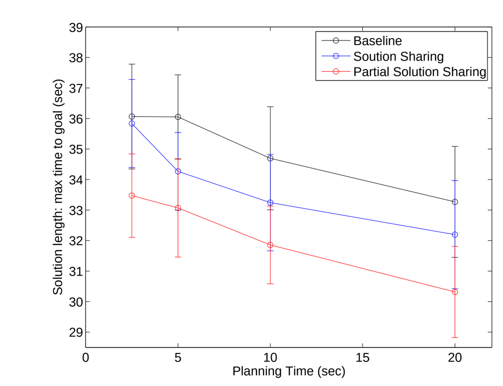
Start and goal configurations (left), and solution (right)



Prairiedog robot



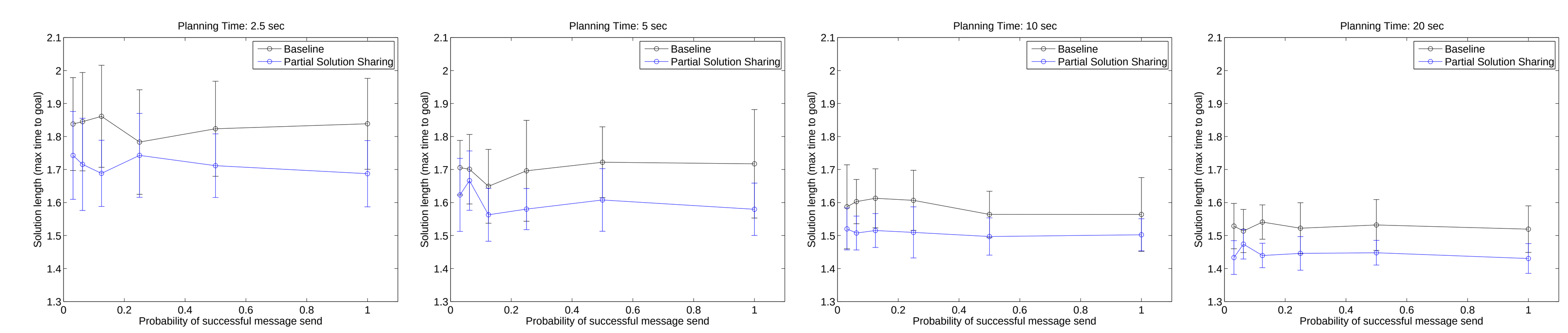
Simulated environment, mean and standard deviation, 20 repeats per point



Real, 20 repeats per point

Example 2: Multi-Robot Task Allocation

n robots are deployed to m goals. Each robots $\rightarrow$ goals mapping is a unique navigation problem. The best solution over all mappings is desired. Each robot works on a different robots $\rightarrow$ goals mapping. Partial solution sharing is used for pruning, but partial solutions cannot be extended by other robots since they correspond to different navigation problems. 6 robots are used in a simulated environment as a proof-of-concept.



Simulated environment, mean and standard deviation, 20 repeats per point

Results

- Significantly outperforms the other centralized algorithms ($p < .0002$).
- Finds similar quality solutions in a fraction of the time.
- Packet drop rates as high as 96.8% have little affect on performance.

Conclusions

- Any-Com lets robots pool resources to solve complex multi-robot navigation and task allocation problems.
- Any-Com enables distributed and collaborative computation, even in harsh (i.e. realistic) communication environments.