Towards Reliable Benchmarking for Multi-Robot Planning in Realistic, Cluttered and Complex Environments

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Motivation

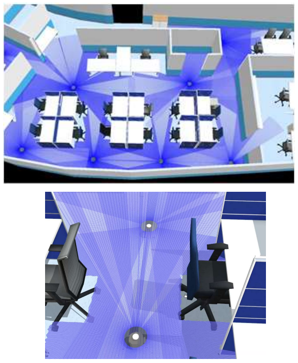
- Develop a benchmarking framework for multi-robot planning and coordination
- Study not only the high-level planning but also the execution aspects. Provide a set of scenarios that resemble realistic robot operations
- Use state-of-the-art open-source robot navigation tools

Related Work

- Focuses on path planning or task planning. Does not study execution and does not consider realistic robot models and environments (often adopts only grids)
- Does not consider state-of-the-art robot navigation stacks

Multi-Robot Planning and Coordination

- Path planning algorithms generate conflict-free paths for a fleet of robots
- The schedules must be designed such that no two agents ever occupy the same cell at the same time step
- Some decentralized approaches coordinate robot movements locally
- Task assignment can be coupled with path planning

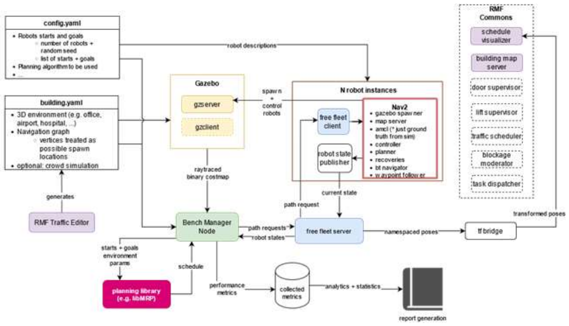


Robot Fleets in the Office Environment

Our Approach

MRP-Bench

- Our approach generates the scenario and the configuration (i.e., start and goal locations, planners to be used)
- MRP-Bench then computes the schedules and starts the simulation and navigation framework (Bench Manager Node, Free Fleet Server, ROS2 Nav2)
- Subsequently MRP-Bench controls the robots, collects the data and visualizes it (Nav2 and OpenRMF components)



config.yaml
- Robots starts and goals
  - number of robots + random seed
  - list of starts + goals
- Planning algorithm to be used
- ...

building.yaml
- 3D environment (e.g. office, airport, hospital, ...)
- Navigation graph
  - vertices treated as possible spawn locations
- optional: crowd simulation

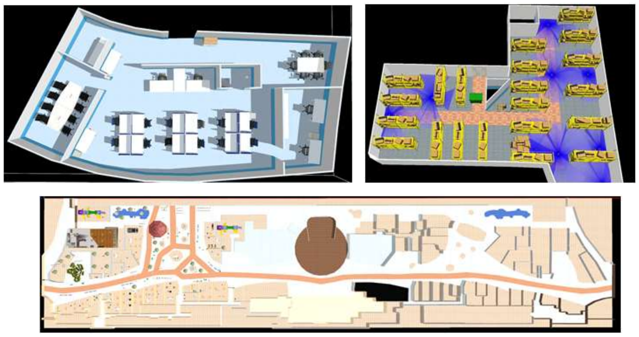
Flow-Chart of the Benchmark Architecture

Metrics

- For planning:
  - Success rate, planning time, makespan, path length
- For execution:
  - Execution time, number of goals reached, minimum distance between any two robots, time each robot cannot move due to being blocked

Algorithms

- Decentralized A*
- Conflict-based search (CBS, ECBS, EECBS)
- Task assignments
- Task assignment coupled with search (CBS-TA, ECBS-TA)



Example Scenarios

Preliminary Results

- Suboptimal algorithms are viable approaches for coordinating multiple robots
- ECBS is faster than CBS and has higher success rates. EECBS is the fastest
- Local recovery of ROS2 navigation can be sufficient to even use decentralized approaches, which is particularly important in rapidly changing environments, where centralized planning generally is too slow or even fails

Algorithm	Office	Warehouse
A*	100%	100%
CBS	99%	83%
ECBS	100%	97%
EECBS	100%	100%

Planning success rate (limit of 60s)

Algorithm	Success Rate			
	Normalized		Overall	
	Office	Warehouse	Office	Warehouse
A*	95%	81%	95%	77%
CBS	93%	84%	92%	70%
ECBS	95%	89%	95%	85%
EECBS	95%	84%	95%	78%

Planning and execution success rates
(limit of 60s and 5min respectively)

Check out the code!
https://github.com/boschresearch/mrp_bench