Multi Robot Route Planning for ROS2

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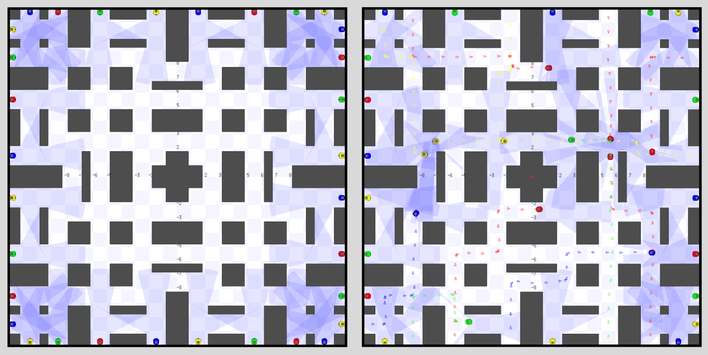
Abstract

This work presents the implementation of a multi robot route planner based on the prioritized planning approach as well as its integration into ROS2 and the well-known Nav2 stack. Further, a method to increase the resilience towards uncertainty and unpredictability in timing during the execution of found routes is introduced. These so-called routing preconditions are shown to be effective on a subset of routing scenarios and offer significant opportunity for further exploration.

Motivation

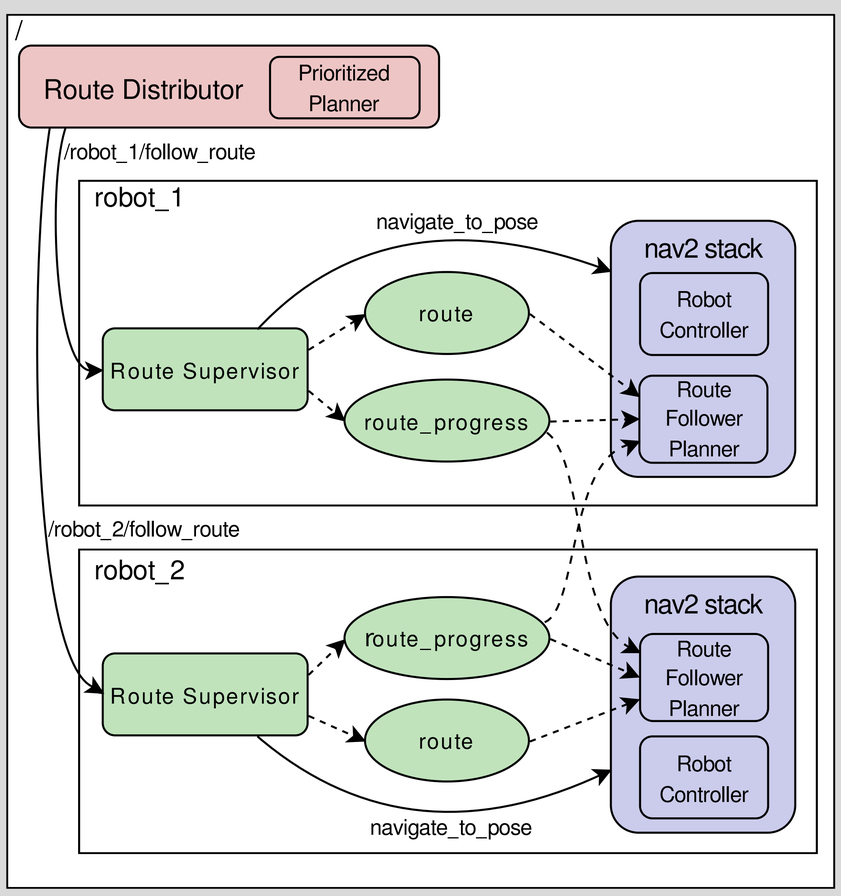
- Multi-Robot-Routing Problem (MRRP) central to multi-robot systems
- Many proposed solutions, few take feasibility of reliably executing found routes into account at the planning stage
- To current knowledge, no publicly available ROS2 package offers a solution to MRRP as well as easy integration into the popular Nav2 navigation stack



Simulation of 12 concurrently navigating robots in a warehouse-like environment

System Architecture

- Central Route Distributor computes routes and publishes them for all robots of the system
- Route Supervisors monitor progress along the current route and keeps all Route Followers up-to-date on it
- The Route Follower Planner Plugin is responsible for ensuring routing preconditions are respected



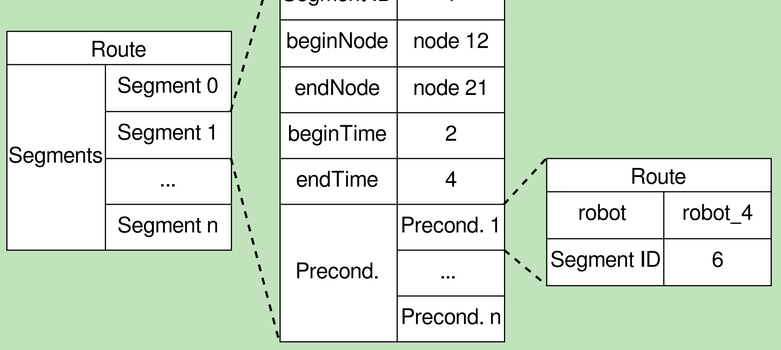
Developed navigation architecture applied to a pair of robots

Prioritized Planning

- Decompose MRRP into series of Single-Robot-Routing-Problems
- Robots on already planned routes represent dynamic obstacles for all further planning processes
- Constrain search space by only allowing wait times as the result of a detected potential collision
- Planner operates on graph representation of environment

Route Representation

- Split into segments representing move from one vertex to neighbor
- Preconditions of a segment are given by other robots expected to pass endNode earlier than beginTime



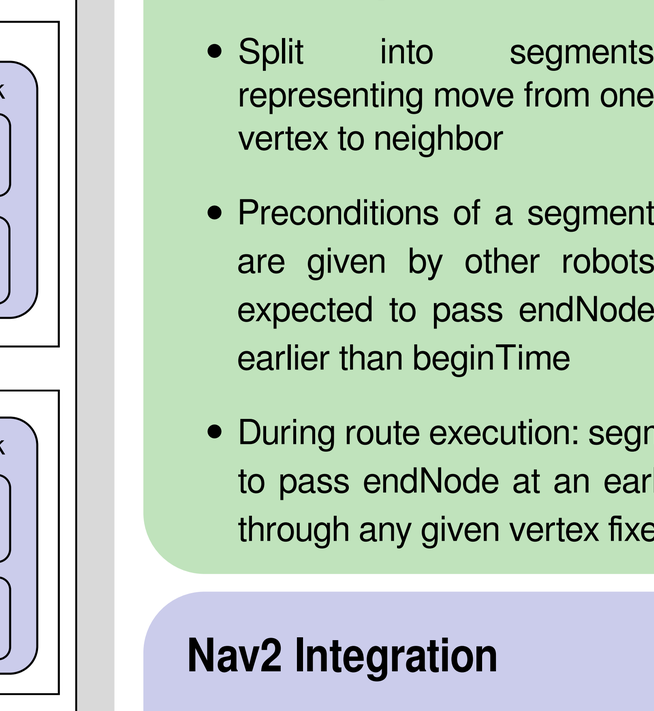
- During route execution: segment may only be executed if all other robots expected to pass endNode at an earlier time have done so → ordering of robots passing through any given vertex fixed, leading to tolerance towards timing uncertainties

Nav2 Integration

- Custom Nav2 behaviour tree and planner plugin allow for compatibility with existing local planners and other Nav2 software components

Experimental Evaluation

- Simulated route execution of 8-32 robots from fixed starting positions to randomized goals
- Roughly linear decrease in individidual success leads to corresponding increase in overall system failure
- Time required to execute routes consistently underestimated by planner
- Identified main causes for failures:
  - ➤ Local planners deviating from strictly defined route
  - ➤ Endless waiting on preconditions reffering to stuck robot



Key Findings

- Planner finding routes for each robot does not gurantee that these routes can be executed without issue
- Routing preconditions effective at countering unexpected deviations in timing but introduce potential for cascading system failure
- Off-the-shelf Nav2 components not suited for working with tightly constrained routes
- Deadlock detection coupled with on-line replanning another avenue for future work

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automation systems