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Distributed vs Centralized Path-Planning and Task-Assignment Solutions for a Fleet of Mobile Warehouse Robots

Cyrill Baumann

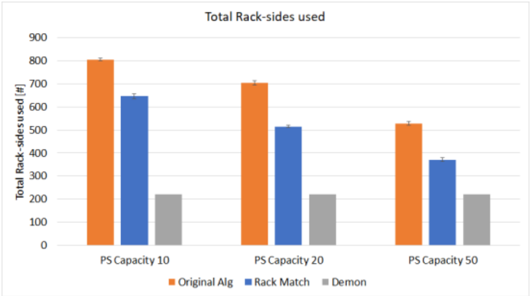
Professor : Alcherio Martinoli
Assistant(s) : Zeynab Talebpour

Nowadays there exist numerous different, often extensively studied possibilities for path planning and task assignment. However, the difficulty lies within choosing the correct approach for a given problem. The goal of this project was to provide an evaluation of the optimality of the chosen algorithms for our industrial partner. Who is operating in the goods-to-person market by offering a robotic solution to transport warehouse racks to a picking station and back to their storage place within the warehouse.

For that purpose, the existing code was abstracted into known decision problems. A proposition of an additional decision level to be introduced into the system resulted from this abstraction. Out of the existing six decision levels I then identified and analyzed the existing algorithms for path planning, robot task assignment (which robot carries which rack) as well as task rack selection (which racks to use to fulfill a given order, knowing that items are on multiple racks within the warehouse) for their optimality and efficiency, but also their limitations and drawbacks.

For path planning, the hybrid approach of the existing system was put into question, and I showed through simulation that without further optimization a centralized approach can handle more than the currently largest warehouse configurations considered by our industrial partner. I therefore proposed and implemented within their system a centralized algorithm (Windowed Hierarchical Cooperative A*). An improvement of approximately 12% less travel time (and travel distance) for every robot could be achieved by this both in simulation as well as during the real robot tests. However, it turned out that the framework was not intended for a centralized approach, which resulted in scaling problems on very large maps due to timing problems between the framework and the algorithm. Therefore, only a proof of concept implementation could be realized.

For the case of a simplified robot task assignment, where all racks (i.e. tasks) have the same priority and the robots do not consider more complex effects for their planning, such as robot congestion of some areas within the warehouse, I did a theoretical evaluation of possible improvement compared to the current algorithm - greedy, selecting closest rack first. This evaluation resulted in a maximal possible improvement of about 1.5% in time, which is not considered significant at the current point of time. Thus, any further effort into robot task assignment has been ceased.



Total rack-sides needed using each algorithm to finish the given set of orders depending on picking station capacity. Demon optimizes over complete set (impossible as tasks are added in real time).

For the task rack selection, I proposed a custom rack match algorithm to improve the random algorithm currently implemented. The goal of the proposed algorithm is to minimize the total number of racks needed to transport to the picking stations by choose the most advantageous rack to fulfil a given order (i.e. rack already on the way). It is built in a modular way, to accommodate for further optimizations (such as prioritizing racks closer to the picking station for example). A reduction of more than 20% racks could be noted in simulation. Independent of the warehouse characteristics such as item distributions or picking station capacities. This algorithm has been fully integrated within the framework and is now part of the core software.