Performance of High-level and Low-level Coordinated Control of Mobile Robots

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Abstract

We analyse the performance of different strategies for coordinated control of mobile robots. These robots are characterized by the non-holonomic kinematic model of a unicycle. The robots are employed for transportation of goods in an environment of a distribution center.

We propose a control architecture, shown in Figure 1, that contains multiple layers of functionality. The high-level control assigns to each robot the reference trajectory. The low-level control takes care that each robot tracks own reference.

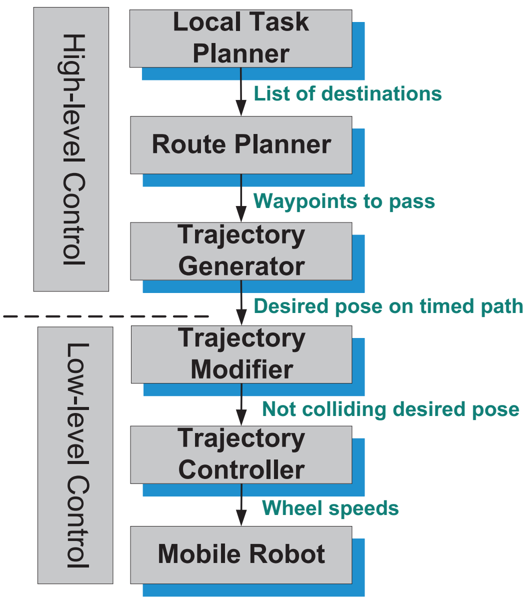

Figure 1: The control architecture

In a distribution center, coordination is needed to guarantee collision-free robot motions and correct robot sequencing. Collisions may occur if there is an obstacle on the robot path or when several robots share the same working space. A correct sequencing of robots is required , since items being transported have to arrive at drop-off points in a specific order based on the customer demands. With our architecture, it is easy to shift responsibilities over coordination of mobile robots to different control layers.

In this work, we investigate performance of two robot coordination strategies. This is done in experiments according to the following scenario: a convoy of seven robots delivers goods along a path where one part of this convoy intersects with another part, so robot coordination is needed to avoid collisions. The coordination strategies are:

1. High-level coordination (HL): at 1 Hz, the robot trajectory generators coordinate their occupation times of intersection, such that only one robot at a time occupies an intersection.
2. Low-level coordination (LL): at 30 Hz, the trajectory modifiers of the robots facing a collision locally override their original reference trajectories using artificial potential fields, such that the robots move away from each other until the imminent collision is averted.

For performance analysis, we consider the following indicators:

- Average travelled time, $\overline{t_{trvl}}[s]$, for all robots to reach their destination.
- Total normalized tracking errors of all robots, $\sum e_{xy}^2[m^2]$, and formation errors $\sum \delta_{ij}^2[m^2]$.

Table 1: Performance Evaluation

Strategies	Indicators		
	$\overline{t_{trvl}}[s]$	$\sum e_{xy}^2[m^2]$	$\sum \delta_{ij}^2[m^2]$
HL	36.06	0.002	0.0014
LL, not coupled	38.458	0.114	0.0021
LL, all robots coupled	38.496	0.123	0.0014

The data given in Table 1 indicate that the high-level coordination leads to shorter travel time and smaller tracking errors. It gives optimal and efficient robot trajectories that are free of collisions. However, this coordination method is less robust to perturbations, since it requires accurate tracking of the reference trajectories. Even though the performance of the low-level coordination is lower, this coordination turns out to be much more robust to uncertainties.

References

[1] D. Kostić, *et. al*, ”Collision-free Tracking Control of Unicycle Mobile Robot” , *in Proc. IEEE Conf. on Decision and Control Shanghai, China*, pp 5677-5672, 2009.