Design, Execution and Analysis of Experimental Campaign for Hybrid Flocking-Formation Control Algorithms

Emna Tourki

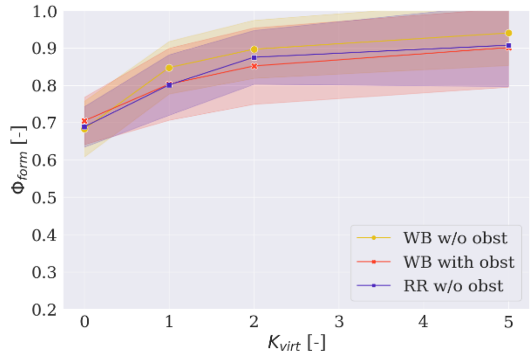
Professor : Alcherio Martinoli
Assistant(s) : Cyrill Baumann

Multi-robot spatial coordination is crucial in a wide range of applications, including search and rescue missions, surveillance or escorting missions, coordinated payload, transportation and spacecraft formations. There exist two main categories of algorithms addressing this challenge: navigation in formation and flocking.

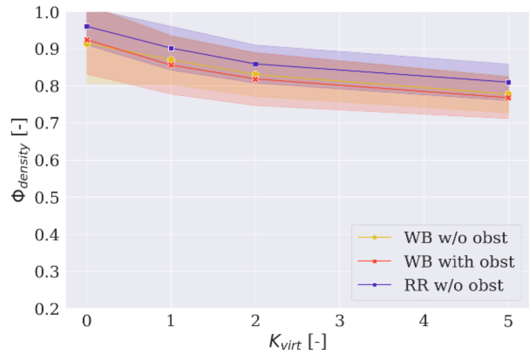
In a previous project, Jonas Perolini proposed three new hybrid algorithms allowing a gradual shift from rigid navigation in formation to flocking and vice-versa: The first algorithm Lapl2Flock is based on Laplacian control. A relaxed circular zone is defined around the agent's desired formation position allowing to loosen the formation. Conversely, the two other algorithms, Pot2Lapl and Flock2Lapl are based on flocking rules combined with additional team objectives allowing to tighten the formation.

In this project, the performance of the three algorithms is assessed in both Webots, a high-fidelity robotics simulator and with real experiments using The Khepera IV robots. To do so, four different metrics are introduced to obtain quantitative results on the algorithms' performances: Φ_{form} determines how close from the desired Laplacian formation the robot's team is. $\Phi_{density}$ gives an insight on the density of the flock in comparison with the optimal flocking density. Φ_{order} assesses how matching the headings and velocities are between the flock members and Φ_{safety} counts the number of agents that are considered too close from one another. All the metrics are normalized between zero and one.

The experiments were designed to show the effect of the key parameters, namely K_{virt} for Flock2Lapl and Pot2Lapl and the relaxed zone radius for Lapl2Flock. Besides this, these experiments should allow to assess whether the algorithms achieve their primary goal which is to smoothly transition from flocking to Laplacian control or vice-versa. Another set of experiments is designed to infer whether the algorithms are scalable when increasing the number of robots.



Pot2Lapl mean formation metric for Webots simulations and real robots experiments with 5 robots



Pot2Lapl mean density metric for Webots simulations and real robots experiments with 5 robots

This report demonstrates that all three algorithms reach their objective.The Flock2Lapl and Pot2Lapl algorithms are especially promising as their additional flocking parameters allow to properly adjust the MRS's behaviour for the considered application better than the concept of a relaxed zone used in Lalp2Flock algorithm. However, the metrics used to assess the performance of the algorithms could be further improved by normalising Φ_{form} for exemple. Overall, the results obtained are very encouraging and motivate the future implementation and testing of the hybrid algorithms in different case scenarios.