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Leveraging Multi-Level Modelling to Automatically Design Behavioral Arbitrators for Multi-Robot Search and Rescue

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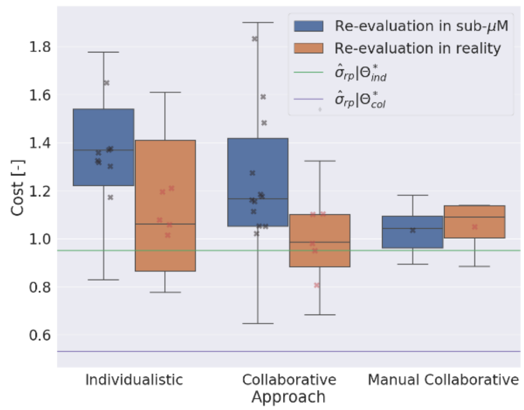
In recent years, the demand for complex automation has been increasing, especially in the field of multi-robot coordination. Among several approaches for automatic controller synthesis, Modeling and optimization of the controller with the Probabilistic Finite State Machine (PFSM) has been recently proposed. Particularly referring to the work by Baumann et al.(2022), which realized the reduction of computational cost during the MDPSO optimization of PFSM with a two-step modeling approach, in a single-robot scenario, I verified that approach with a more complex multi-robot scenario. More precisely, a behavior-based controller for a multi-robot exploration scenario is synthesized automatically, using a predefined set of basic behaviors and conditions. A key characteristic of the synthesizing approach is the use of a microscopic model (the first step) to significantly reduce the computational cost involved.

In this work, the use of modeling is extended to assess the best achievable performance analytically. To this end, a simplified macroscopic model of the scenario is leveraged to obtain the best achievable performances given an ideal controller, subject to real constraints such as limited speed and localization. Taking advantage of the nature of the scenario, as well as the interpretability of the synthesized PFSM-based arbitrators, individualistic and collaborative controllers are analyzed separately, giving insights into the theoretical and experimentally observed impact of collaboration for the considered case study. The macroscopic analysis provided an accurate upper bound for the performance of individualistic controllers. Due to several approximations used in the modeling, the upper bound for the performance of collaborative controllers was observed to be somewhat optimistic.

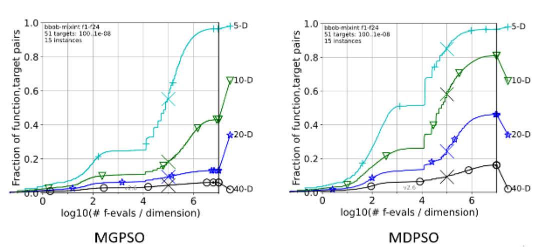
The results obtained show that the PFSM-based arbitrator synthesis approach is equally viable for multi-robot scenarios and results sometimes in competitive performances with a manually designed solution when the optimizer



Comparison of the re-evaluated PFSM-based arbitrators in both sub-μM and in reality.

succeeds to learn collaborative controller, as shown in the figure above. However, Inappropriate parameter learning was also sometimes observed and it resulted in poor performance.

With this results, an supplemental assessment of the optimizers was conducted to verify the varidity of our optimization approach. I also referred and implemented another algorithm, MGPSO, which was designed for multi-objective problems by Scheepers et al. (2019), as a target of performance comparison of MDPSO. The benchmark results suggested that MDPSO works better than MGPSO in all three type of problems, but further inspection of MGPSO is needed for precise conclusion.



Comparison of the optimization performances for noiseless mixed-integer continuous problems.