Automatic Design of a Behavioral Arbitrator for Khepera IV Robots using Particle Swarm Optimization

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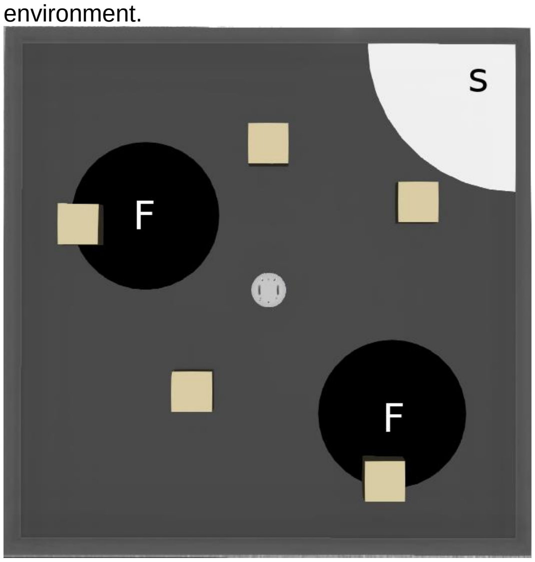
The implementation and tuning of controllers in mobile robot systems remains predominantly a manual task. In the literature, an alternative approach consists in building a controller by combining some very basic behaviors such as “follow light”, “stop”, “avoidance” together with very basic conditions such as “obstacle detected”, “floor is white” and so forth into a probabilistic finite state machine (FSM). The structure and tuning of the FSM can be done either manually or by an optimizer with regards to a provided scenario, in this context, a simple foraging one in a cluttered environment.



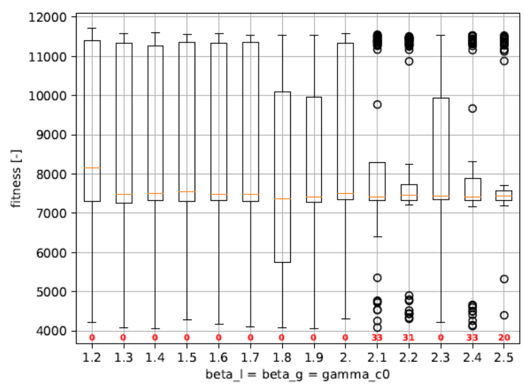
Simple foraging task used in this project (F: food, S: start zone)

For the optimization, the solution adopted here is to use a variant of the Particle Swarm Optimization algorithm known as Mixed-Discrete Particle Swarm Optimization (MDPSO), the main reason being that it handles mixed discrete-continuous problems allowing to optimize the structure of the PFSM (which and how many behaviors, which and how many transitions) and simultaneously tune their respective parameters. It also introduces a diversity preservation mechanism.

The MDPSO algorithm was first extensively validated on continuous and mixed-integer non-linear problems (MINLP). For low dimensional (up to 5-10) and few constraints, the algorithm can often find the absolute minima whereas for higher dimensional cases (10, up to 50), it sometimes has difficulty finding the feasible subregion.

Due to the recentness of the algorithms, only guidelines are available for the choice of meta-parameters for MDPSO. Therefore, a method to tune the optimizer itself is explored. To find the appropriate meta-parameters the target scenario was used as a benchmark and iteratively different meta-parameters were tested. With this approach, the desire was to select the meta-parameters that, on average, consistently produce PFSM that have a good fitness score on a foraging task.

The computational complexity of the high-fidelity simulator used makes this meta-optimization slow, therefore an alternative, non-spatial micro-simulator of the target scenario is proposed for the meta-optimization, where the non-spatiality greatly accelerates the process.



Example of meta-parameter tuning. For $\beta_l = \beta_g = \gamma_{c0} = 1.8$ *on average better PFSM are generated.*

The proof of concept of the meta-parameter optimization shows promise but the spread remains large. A mesh grid approach is believed to be more suitable rather than the iterative approach used. The implementation of the optimizer is modular and allows an easy way of the introducing other benchmarks and target scenarios.