Broadening Applicability of Swarm-Robotic Foraging Through Constraint Relaxation

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Swarm robotics (SR) offers promising solutions to real-world problems that can be modeled as foraging tasks, e.g. disaster/trash cleanup or object gathering for collective construction. In this context, robots collect and transport material from one or more sources, and bring the collected material to a known nest location. Intermediate locations called caches can be utilized or ignored by robots, depending on what foraging strategy they are employing, and serve as temporary storage sites where materials can be dropped and picked up asynchronously. Caches can serve as a means of traffic control, regulating congestion by enabling spatially disjoint task execution [4].

When tackling a foraging task, the choice of employing task partitioning (i.e. dividing a large task into disjoint subtasks to increase performance) is equivalent to deciding the object transfer method. If partitioning is not employed, then no transfer occurs, and a single robot carries an object from the source to the nest (Generalist in Fig. (1)). If partitioning is employed, then object transfer can be direct (robotic object handoff) [1], [4] or indirect [3], [5], [2], and use caches as asynchronous pickup/drop points. We propose a communication-free method based on local perception to relax constraints present in previous work:

- All robots have a priori knowledge of object/cache locations [1], [5], [2], [3]. This does not model partially observable/unstable environments, which are some of the most prominent applications for SR systems.
- All robots that cross over a cache area must pay a usage penalty[1], even if they do not utilize it. This restriction models an area of rough terrain that requires extra time to navigate safely, for which task partitioning is clearly advantageous.
- All robots executing the unpartitioned task must use a very long corridor to travel between the source and the nest [5], [3]. This restriction models environments in which debris/obstacles block the direct path between the source and the nest, and it is therefore slower to execute the unpartitioned task in general.

Per-robot stochastic decisions on strategy selection are based on its local estimates of the average execution/interface time of tasks associated with each strategy. Robots move through the graph given in Fig. (1), (possibly) changing allocations upon task completion/abortion.

We show in simulation that the proposed methods gives rise to a robust, adaptive foraging strategy which employs task partitioning to divide the foraging task into independent subtasks (Collector/Forager), or to employ a non-partitioning strategy and tackle the foraging task holistically (Generalist), whichever is better suited to current environmental conditions. Even under the proposed constraint relaxation, our approach demonstrates that under some combinations combinations of swarm sizes, robot capabilities, and environmental conditions, employing task partitioning still provides performance increases in comparison with an unpartitioned strategy. This work moves SR foraging approaches closer to a more broadly applicable real-world model, showing them to be effective even under ideal conditions continuing to perform robustly in conditions simulating more volatile environments.

REFERENCES


