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Generalizing Task Partitioning Approaches To Robot Swarm Foraging

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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. 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 the 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 [1].

In 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. If partitioning is employed, then object transfer can be direct (robotic object hand-off) [2], [1] or indirect [3] using caches as asynchronous pickup/drop points.

In our communication-free method based on local perception we relax some strong constraints from previous work:

- All robots have *a priori* knowledge of object/cache locations [2], [3]. This does not model partially observable/unstable environments, which are important applications for SR systems.
- All robots that cross over a cache area must pay a usage penalty [2], regardless of utilization. Though this models rough terrain requiring extra time to navigate safely, it also clearly incentivizes partitioning strategies.
- All robots that do not partition tasks must use a very long corridor to travel between the source and the nest [3]. This restriction models environments in which obstacles block a direct foraging path, and also provides an advantage to partitioning strategies.

In our approach, each robot determines its own way of doing tasks based on local estimates of the average execution time and interface time of tasks associated with each strategy (computed from a robot's previous executions of the task). The two main decisions robots make (i.e., whether to abort their current task and whether to employ task partitioning) use deviations (plus or minus) from a robot's estimate of execution/interface time to stochastically choose what to do during foraging.

We use the "depth" of the partitioning strategy (i.e how many times the robot can choose to partition the foraging task as it decides its allocation) in order to differentiate non-partitioning approaches (depth 0) from partitioning approaches (depth > 0). In this work robots have only a single opportunity for partitioning.

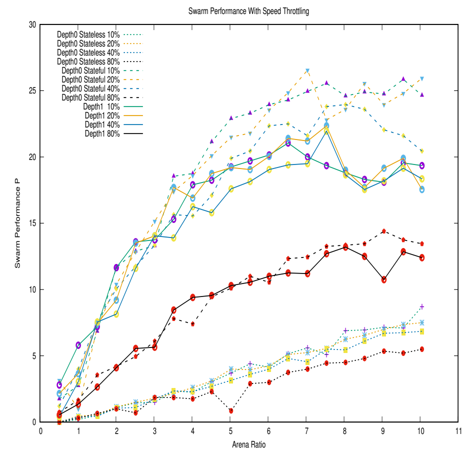

Fig. 1. The total number of blocks collected by all controllers, varying the throttle applied on block carry (modeling different object weights/robot capabilities/environmental conditions). The two Depth 0 controllers (one with memory and one without) always execute the unpartitioned task.

We conducted experiments in simulation showing that our proposed method gives rise to a robust, adaptive foraging strategy which employs a partitioning or a non-partitioning strategy depending on which one is better suited to current environmental conditions. Specifically, in Fig. 1 we show that there is a range of conditions for low to mid swarm densities for which employing task partitioning still provides performance increases in comparison with an unpartitioned strategy, despite the constraint relaxation described earlier.

This work broadens the applicability of SR foraging approaches, showing that they can be effective under more ideal conditions while continuing to perform robustly in more volatile/challenging environments.

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