Swarm-Intelligence-based Multi-Robot Task Allocation *

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ABSTRACT

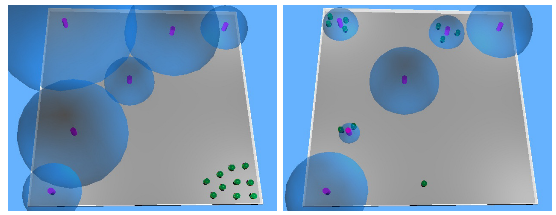
Multi-Robot Task Allocation (MRTA) in an unknown environments is a core problem in automated systems. To complete all tasks in the environment, three distinct steps are needed to be performed: exploration, task allocation, and task execution. We propose a hierarchical algorithm based on swarm intelligence to perform these three steps concurrently in order to improve the overall system performance. The proposed algorithm is a heuristic solution for a class of MRTA problems, named ST-MR-IA, which is NP-hard [3].

Background and Contribution While task allocation problems are challenging in general, the level of challenge is raised even further in unknown or dynamic environments. Gerkey and Matarić [3] classified MRTA problems along three dimensions: (1) Single-task robots (ST) versus multi-task robots (MT), referred to capabilities of robots for parallel task execution. (2) Single-robot tasks (SR) versus multi-robot tasks (MR), referred to required number of robots to complete a task. (3) Instantaneous assignment (IA) versus time-extended assignment (TA), referred to the task allocation plan of robots and level of information available for robots.

Heuristic approaches recently proposed for MRTA problems, assume either known environments with predetermined number of tasks or single-robot tasks which do not need any cooperation between robots ([3] and references therein). In [2] four different heuristic approaches were proposed for the task allocation of ST-MR-TA. In that work, if a robot has completed its share of a task, it communicates the location and the progress of the task to the others, implying that the approach is sequential in nature. We improve the state of the art by addressing the problem of *multi-robot* tasks in *unknown environments*: multiple homogeneous robots need to explore an unknown environment and reconnaissance stationary objects (tasks) of interest, as well as to cooperate to locate tasks and execute them.

Example Fire fighting in an unknown environment: tasks are fire sources and should be extinguished by cooperative robots, which do not have a priori knowledge about the environment and tasks' locations. The time required to complete the tasks (find, allocate and execute them) is important. Although each task may be completed by one robot, more robots can complete it faster.

Proposed method We propose a two-level decentralized algorithm for robots to collaborate to find and perform tasks concurrently: (i) At the exploration level of the algorithm, robots use a Bee-Swarm Optimization (BSO) based algorithm to explore the environment and find unallocated tasks. This algorithm brings randomness to exploration, which is necessary for searching more unknown areas and preventing robots from being trapped in local optimum [1]. When a new unallocated task is found, robots automatically form a new coalition to perform actions on the task; this can be done through the Most Proximal Task First approach [2]. Dynamically formed coalitions help the multi-robot system to assign more robots to the task which needs more actions. (ii) At the exploitation level of the algorithm, after coalition formation, robots in a team cooperate with each other to find the exact position of a task, surround it and perform actions on it. At this level, robots collaborate by using an algorithm based on Particle Swarm Optimization (PSO) [4], which is shown to converge fast to its optima.



(a) Iteration 1 (b) Iteration 4000

Figure 1: Two states of the environment with 6 tasks and 10 robots

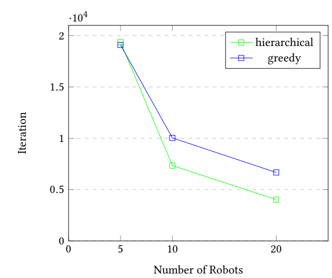


Figure 2: Averaged number of iterations over 20 runs for different number of robots

Efficiency of the proposed method We conducted a set of simulation tests using the Webots simulator [5]. Robots were assumed to know their global GPS positions but did not have a priori knowledge about the environment or the tasks. Tasks were located randomly in the environment during different runs. Figure 1 shows two states of the environment with 6 tasks and 10 robots using the proposed hierarchical algorithm. As an example, the average number of iterations over 20 runs to discover and complete 6 tasks in an unknown environment for different number of robots is shown in figure 2. The results are compared to a greedy approach in which all robots create one coalition and execute one task at a time.

REFERENCES

[1] H. Ataei, K. Ziarati, and M. Eghtesad. 2013. A BSO-based algorithm for multi-robot and multi-target search. In *Int'l. Conf. on IEA/AIE.*

[2] P. Dasgupta. 2011. Multi-robot task allocation for performing cooperative foraging tasks in an initially unknown environment. In *Innovations in Defence Support Systems-2.*

[3] BP. Gerkey and MJ. Matarić. 2004. A formal analysis and taxonomy of task allocation in multi-robot systems. *The Int'l. Journal of Robotics Research* (2004).

[4] J. Kennedy and R. Eberhart. 1995. Particle swarm optimization. In *Neural Networks, 1995. Proceedings., IEEE International Conference on.*

[5] O. Michel. 2004. Cyberbotics Ltd. Webotsffl: professional mobile robot simulation. *Int'l. Journal of Advanced Robotic Systems* (2004).

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