MO-LOST: Adaptive ant trail untangling in multi-objective multi-colony robot foraging

(Extended Abstract)

Zhao Song
School of Computing Science
Simon Fraser University
Burnaby, BC, Canada
zhaos@sfu.ca

Seyed Abbas Sadat
School of Computing Science
Simon Fraser University
Burnaby, BC, Canada
sas21@sfu.ca

Richard T. Vaughan
School of Computing Science
Simon Fraser University
Burnaby, BC, Canada
vaughan@sfu.ca

ABSTRACT

In the context of large-population multi-objective robot foraging, we present a novel ant-inspired trail-following algorithm that is able to adaptively untangle multiple trails. The emergent result is often a set of short, non-intersecting trails that produce good system throughput due a good trade off between the dual goals of minimizing travel distance and spatial interference. Empirical simulation experiments with up to 200 robots suggest that the method can usefully improve performance in practice.

Categories and Subject Descriptors

I.2 [**Artificial Intelligence**]: Robotics

General Terms

Algorithms, Experimentation

Keywords

Velocity obstacle, Multi-robot systems, obstacle avoidance

1. INTRODUCTION

We consider the classical problem of having multiple robots locate a source of resources and transport them to a sink location, repeating indefinitely. Robots use an instance of the general ant algorithm [1] to navigate between source and sink. The first demonstration of ant algorithms for this problem was by Iredi *et al*[2]. Iredi's abstract "ants" have no physical extent and so do not suffer from spatial interference, so the intersection of trails for different objectives was not problematic. Aiming for a practical system, we use a system of virtual pheromones implemented by wireless communication of waypoints in a shared localization space [4]. Sadat *et al* showed that maintaining spatially separated trails tends to keep robots apart and allows them to spend most of their time making progress towards their goals, thus increasing system throughput [3]. However, in multi-objective robot foraging problems we observe that SO-LOST often creates trails that are longer than necessary, and often has trails crossing at right-angles. Below we present a novel adaptive trail-following algorithm that is able to untangle many trails to create non-intersecting, thus low-interference, trails.

Appears in: *Proceedings of the 11th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2012)*, Conitzer, Winikoff, Padgham, and van der Hoek (eds.), 4-8 June 2012, Valencia, Spain.

2. MULTI–OBJECTIVE LOCALIZATION–SPACE TRAILS

We introduce a new ant algorithm called *Multi-Objective Localization-Space Trails* (MO-LOST) which extends and improves upon Sadat's SO-LOST and Vaughan's LOST methods. The details of LOST can be found in [4]. Spaced-Out LOST is a simple extension that modifies the robot's trail-following behaviour, and thus influences subsequent trail formation. In SO-LOST, when a robot is close to a waypoint that is *not* for its current goal, it will shift its velocity vector slightly left compared to the trajectory suggested by unmodified LOST (if local obstacles permit). Thus the fresh trail being laid by the robot will be slightly left of the previous trails. In the single-objective foraging problem examined by Sadat, there were two main trails after convergence; one from home to source and one returning. With the trails in opposite directions, the left shift repeatedly applied has the effect of spreading out the trails in space. SO-LOST is symmetric with respect to the currently assigned task, so there is no way to shift some trails preferentially to others. In multi-objective, multi-colony scenarios this is not always a good idea, as illustrated in Figure 1. Initially-intersecting trails (Fig. 1(top left)) should be de-intersected so that the total trail length is minimized (Fig. 1(bottom right) . MO-LOST extends SO-LOST so that when robots encounter trail intersections, only the longer trail is left-shifted. This asymmetry tends to leave shorter trails intact while wrapping longer trails around them. In large population sizes where trail intersection causes a lot of costly spatial interference, this non-intersecting short-trail configuration is optimal.

Intuitively, the robot moves toward the nearby waypoint labelled with the robot's current task that would take it nearer to its goal. If there is an waypoint labelled with another task nearby (i.e suggesting an interfering trail), that waypoint is tested to see if either (i) it is closer to its goal Place than the on-task waypoint or (ii) it belongs to a task which is cheaper on average than the robot's task. If either of these conditions hold, the robot shifts its driving left slightly to avoid the interfering waypoint in future. This action is shown schematically in Figure 1.

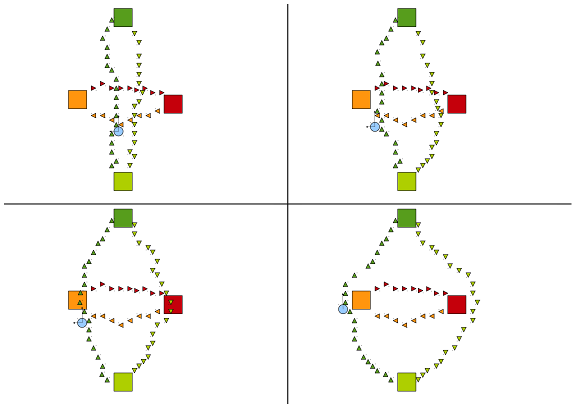

Figure 1: MO-LOST in action. On encountering a waypoint from a shorter trail, robots shift their trajectory slightly to the left. Over time the longer trail wraps around the shorter trail, avoiding intersection and thus reducing spatial interference between robots, while preserving short trails.

3. EXPERIMENTAL RESULTS

We use the well-known Stage simulator to compare the performance of MO-LOST with its predecessors SO-LOST and LOST in a variety of task environments and population sizes. The world size is fixed at 20x20m and contains no fixed obstacles. Robots are Stage's Pioneer 3DX (0.45m long) and SICK LMS200 scanning laser rangefinder models.

Robots are identical except for their permanent task assignment - equal numbers to each task - and starting pose which is the same in each trial, chosen at random and uniformly distribed in the world. Robots start with no information about the location of source and home and must find them by exploration at the start of the trial.

In the screenshots below, Places are large squares, with sources green and homes red. Robots are small red octagons, drawn with yellow diamonds when traveling home with resources. Tiny dots are individuual waypoints stored by one robot. Medium-sized squares in shades of blue are a normalized two-dimensional histogram of robot locations over the previous few minutes. The histogram tends to show the emergent trails quite clearly, with darker blue indicating more defined trails. Recall that "trails" are only perceived by the reader in the pattern of robot behaviour and not represented explicitly by the system.

For lack of space, we present only a selection of results here, in Fig. 2. The performance plot shows that for many population sizes MO-LOST outperforms SO-LOST, while both of these frequently outperform LOST considerably. A T-test shows that MO-LOST outperforms SO-LOST and LOST in most cases, except for the pairs indicated with dotted ellipses. These are most frequent at very low population sizes, where interference is insignificant, and in some easy problems, where MO-LOST was at no advantage over SO-LOST.

4. CONCLUSION

This is the first example of a method to untangle intersecting ant trails from multiple tasks. When trails intersect, the shorter trail is preserved and the longer trail moved, which tends to produce shorter total trail lengths. We determined empirically from a simulation study that Multi-Objective LOST often outperforms Spread-Out LOST and LOST, the original proposal for practical multi-robot foraging using ant-like trails. The performance benefits are most clear in large populations. While MO-LOST is not always applicable, we believe that MO-LOST may be the most practical algorithm yet described for very large population near-decentralized multi-robot, multi-objective foraging from sources to sinks.

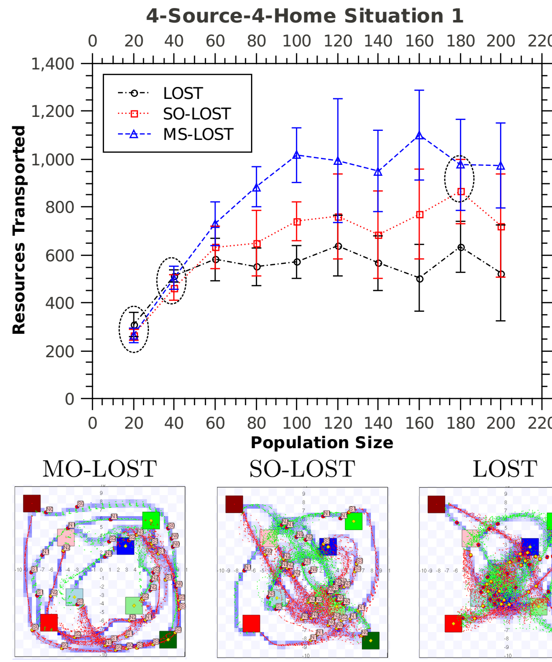

Figure 2: Results: Four-task problems, showing performance vs. population and example trail configurations at the end of a 30 minute trial.

. All results have statistically significant difference except where marked with a dotted ellipse.

5. REFERENCES

[1] M. Dorigo. Optimization, learning and natural algorithms. *PHD thesis, Politecnico di Milano, Italy*, 1992.

[2] S. Iredi, D. Merkle, and M. Middendorf. Bi-criterion optimization with multi colony ant algorithms. In E. Zitzler, L. Thiele, K. Deb, C. Coello Coello, and D. Corne, editors, *Evolutionary Multi-Criterion Optimization*, volume 1993 of *Lecture Notes in Computer Science*, pages 359–372. Springer Berlin / Heidelberg, 2001.

[3] A. Sadat and R. T. Vaughan. So-lost: An ant-trail algorithm for multi-robot navigation with active interference reduction. *In Proceeding of the Twelfth International Conference on Aritifical Life (ALife XII)*, August 2010.

[4] R. T. Vaughan, K. Stoy, A. Howard, G. S. Sukhatme, and M. J. Mataric. Lost: Localization-space trails for robot teams. *IEEE Transactions on Robotics and Autonomous System*, 18(5):796–812, 2002.