An Ant Algorithm for Multi-Robot Navigation and Distributed Simultaneous Task Allocation

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Abstract— **This paper describes multi-robot foraging in an unknown environment with an unknown number of sources and single sink (home). The goal is to effectively allocate robots to sources with least interference and maximum rate of resource collection. The navigation between source and sink is achieved by using trails of virtual landmarks inspired from ant-like trail laying behaviour.**

The algorithm is tested in simulation with varying number of robots and sources. The result indicate that our method achieves near optimal allocation of robots to different sources.

I. INTRODUCTION

We present an algorithm for the classical *resource transportation* task in an unmapped environment. Robots start from arbitrary positions and search for a supply of resources. On reaching the source, they receive a unit of resource and return home with it, then return to fetch more resource repeatedly for the length of a trial [**?**]. Our main focus in this paper is finding task allocation that maximizes the rate of collection of the resources (our throughput) and with minimum congestion in trails. These two goals are mostly overlapping, hence we achieve the former by trying to solve the latter.

The earlier works [**?**] for this task present localization-space trails which is an implementation of ant-inspired trail following for imperfectly-localized robots. In that algorithm, robots generate and share trail data structures composed of waypoints specified by reference to task-level features. The trails are continuously refined online, and maintain the ant-algorithm property [**?**]DORIGO1992) of converging to near-optimal paths from source to home.

In the LOST and other ant-algorithm methods, they use traveling time as the distance function to be optimized, by which the discovered paths can be longer in space but shorter in time since they spread robots out to minimize mutual spatial interference between robots. By increasing the population size, these interferences eventually dominate the traveling cost. However, since ant algorithms tend to converge to a single best trail, in a large population this train can become congested. On the other hand, the behaviour of the ant algorithms (including LOST) is to explore the environment to discover the target while finding the shortest path to that, so in the case of multiple sources they can not perform well since they try to minimize a path to a random source (it might be the closest one). We modified the original algorithm such that it does not converge to a single source as it would result in better throughput.

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In this paper we describe a modification to the existing LOST algorithm that improve performance in the case of multiple sources and a large number of robots as well as maintaining the same performance in a single-source, single-sink setting with less number of robots. We were able to get superior performance in most of the test-cases we examined.

II. RELATED WORKS

We studied Localization-Space Trails (LOST) and its versions as an ant-inspired trail following algorithm which is suitable for imperfectly localized robots. The method is to generate and share short-lived waypoints (*crumbs)* by robots, which contain some information (estimated distance to target, time to target, density of waypoints, to-source or to-sink label). By following these crumbs, robots can find optimal path between source and home. In the Spread-Out Localization-Space Trail (SO-LOST) which is a modified version of LOST, it tries to increase the scalability by minimizing mutual spatial inference between robots which is done by shifting crumbs in a trail from source to home and home to source for a single source, single sink. In the Multi-Objective Localization-Space Trail (MO-LOST) it tries to reduce mutual spatial inference for paths from multiple sources, multiple sinks by shifting the crumbs of a trail which is crossing other crumbs of the other trails. In the Blinkered Localization-Space Trail (Blinkered LOST) it tries to modulate the field of the view (FOV) of the robots' trail-detecting sensor. it shows that the global throughput is a function of robot FOV, means that with narrower FOVs, it performs better in large populations, since narrrower FOV causes multiple trails to be maintained, so that the system can support larger population sizes before saturating due to inference.

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TABLE I
AN EXAMPLE OF A TABLE

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APPENDIX

Appendixes should appear before the acknowledgment.

ACKNOWLEDGMENT

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References are important to the reader; therefore, each citation must be complete and correct. If at all possible, references should be commonly available publications.

REFERENCES

[1] G. O. Young, Synthetic structure of industrial plastics (Book style with paper title and editor), in Plastics, 2nd ed. vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 1564.

[2] W.-K. Chen, Linear Networks and Systems (Book style). Belmont, CA: Wadsworth, 1993, pp. 123135.

[3] H. Poor, An Introduction to Signal Detection and Estimation. New York: Springer-Verlag, 1985, ch. 4.

[4] B. Smith, An approach to graphs of linear forms (Unpublished work style), unpublished.

[5] E. H. Miller, A note on reflector arrays (Periodical styleAccepted for publication), IEEE Trans. Antennas Propagat., to be publised.

[6] J. Wang, Fundamentals of erbium-doped fiber amplifiers arrays (Periodical styleSubmitted for publication), IEEE J. Quantum Electron., submitted for publication.

[7] C. J. Kaufman, Rocky Mountain Research Lab., Boulder, CO, private communication, May 1995.

[8] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, Electron spectroscopy studies on magneto-optical media and plastic substrate interfaces(Translation Journals style), IEEE Transl. J. Magn.Jpn., vol. 2, Aug. 1987, pp. 740741 [Dig. 9th Annu. Conf. Magnetics Japan, 1982, p. 301].

[9] M. Young, The Techincal Writers Handbook. Mill Valley, CA: University Science, 1989.

[10] J. U. Duncombe, Infrared navigationPart I: An assessment of feasibility (Periodical style), IEEE Trans. Electron Devices, vol. ED-11, pp. 3439, Jan. 1959.

[11] S. Chen, B. Mulgrew, and P. M. Grant, A clustering technique for digital communications channel equalization using radial basis function networks, IEEE Trans. Neural Networks, vol. 4, pp. 570578, July 1993.

[12] R. W. Lucky, Automatic equalization for digital communication, Bell Syst. Tech. J., vol. 44, no. 4, pp. 547588, Apr. 1965.

[13] S. P. Bingulac, On the compatibility of adaptive controllers (Published Conference Proceedings style), in Proc. 4th Annu. Allerton Conf. Circuits and Systems Theory, New York, 1994, pp. 816.

[14] G. R. Faulhaber, Design of service systems with priority reservation, in Conf. Rec. 1995 IEEE Int. Conf. Communications, pp. 38.

[15] W. D. Doyle, Magnetization reversal in films with biaxial anisotropy, in 1987 Proc. INTERMAG Conf., pp. 2.2-12.2-6.

[16] G. W. Juette and L. E. Zeffanella, Radio noise currents n short sections on bundle conductors (Presented Conference Paper style), presented at the IEEE Summer power Meeting, Dallas, TX, June 2227, 1990, Paper 90 SM 690-0 PWRS.

[17] J. G. Kreifeldt, An analysis of surface-detected EMG as an amplitude-modulated noise, presented at the 1989 Int. Conf. Medicine and Biological Engineering, Chicago, IL.

[18] J. Williams, Narrow-band analyzer (Thesis or Dissertation style), Ph.D. dissertation, Dept. Elect. Eng., Harvard Univ., Cambridge, MA, 1993.

[19] N. Kawasaki, Parametric study of thermal and chemical nonequilibrium nozzle flow, M.S. thesis, Dept. Electron. Eng., Osaka Univ., Osaka, Japan, 1993.

[20] J. P. Wilkinson, Nonlinear resonant circuit devices (Patent style), U.S. Patent 3 624 12, July 16, 1990.