Report on: Design of ant-inspired stochastic control policies for collective transport by robotic swarms

Aniket Gujarathi

***Abstract*— In this report, we briefly discuss the main ideas explained in [1] regarding collective transport by robotic swarms using enzyme-inspired boundary coverage strategy. We further propose an extension to the given problem to use a temporary-leader follow strategy for efficient transport.**

I. INTRODUCTION

Collective transport is a distinctive trait found only in humans and ants due to the high level of coordination required and adaptability to uncertain scenarios. Works like [2], [3], [1] perform experiments on Aphaenogaster Cockerelli ants and design a stochastic controller that mimics the ant behaviour in the context of collective transport of large loads. The main contribution of [1] is the design of three stochastic controllers that depend on an enzyme inspired boundary coverage strategy [3]. Based on this enzyme inspired strategy, the authors propose three methods of designing the robot control policies to mimic ant behaviour.

The Equilibrium Population Matching Method (EPMM) is used to control the attachment-detachment probabilities of robots to guarantee that the Front and Back robot populations match the observed ant data. This method uses two Chemical Reaction Networks (CRNs) for the Front and Back populations independently to estimate the absolute encounter rates according to a target mean allocation. The Transient Matching Method (TMM) is used to choose the precise bounding and unbounding probabilities such that the transient dynamics of the ants are satisfied with a desired convergence rate. Finally, the Rate Matching Method (RMM) is used to control the flux of the robots joining and leaving the load boundary during transport. This can be useful when frequent load attachment/detachment is risky for the load (eg. the load is brittle).

II. POSSIBLE IMPROVEMENTS

[1] proposes stochastic control policies to mimic ant behaviour for boundary coverage and flux control, but does not talk about the actual transport phase. An improvement to this paper could be the addition of a temporary leader-follow strategy for better transport. Another drawback mentioned in the paper was that the attachment/detachment never turns off as the controller is always adapting to the environment. However, in cases where this is not a concern, an efficient approach would be to transition to another system-level mode. Finally, the paper could also be extended to handle non-circular loads and for other useful applications such as search-and-rescue, collaborative water body cleaning, etc. In this report, we will extend on the temporary leader follow strategy for transport phase.

III. TEMPORARY LEADER FOLLOW STRATEGY

According to [4], while the combined force of the group determines the speed of the load, it is individual informed ants that steer the direction of movement. The authors further state that freely moving ants are well informed of the correct nest-bound direction, but this information degrades as the ants bind to the load. One reason could be the obstruction of ant's antennae by the load. Hence, we propose the idea of a temporary leader to steer the load in correct direction.

Let us assume that some free robots know the direction of the goal (nest), but lose the information periodically once they are bound to the load. However, during the binding process, this free robot, steers the load to the direction of the nest and the remaining team of robots apply force parallel to the leader's force vector. We also assume that the team around the load boundary are able to sense when a leader is attached to the payload. Although the EPMM and the TMM policies would be the same for equilibrium allocation as they are related to boundary coverage, RMM would have to change given the leader transitions. As RMM decides the flux of the ants attaching and detaching, whenever a leader ant comes near the load, the attached ant is bound to free up the space for the leader to attach. As the leader contains accurate information of the goal position, it introduces this information as it attaches to the load and steers the load in the direction of the goal. However, this leader gradually loses on its information after attaching. As a result, the load may drift after sometime till another leader ant attaches to the load. However, given this stochastic behavior, the dynamics will surely fluctuate but will eventually converge to the correct solution.

IV. FUTURE WORK

Future work could include an investigation into designing a model where communication between the leader and the load carrying robots do not occur similar to how ants actually behave. Another pathway for future research could be to design stochastic planning frameworks to reach the goal in continuously changing environments. The current method does not talk about adversarial agents in the environment. We could extend the idea to handle ant robots that may contain false or improper information and how the swarm can detach such robots efficiently from the system.

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