Collective Mapping Using Unlocalized Swarm Robots

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Abstract

Terrain recognition is a fundamental task for swarm robotics. As a multitude of robots are used, they need to have low unit cost in order to be viable, which directly reflects in restricted processing and sensing data, including lack of localization. The limited information poses a challenge on effectively exploring the area. The proposal is to provide an effective topological mapping of unknown areas using a swarm of autonomous robots with multiple starting points and encounter-based information sharing to obtain a map of a bounded area. Each robot builds its own map based on its exploration, and when it encounters other robots, they sum their map information until a fully bounded map is found.

1 Introduction and Background

Swarm robotics is a type of multi-robot system in which a large group of relatively simple autonomous agents are designed for a collective behavior based on their individual interactions with the environment, with each other and their goals. In many situations, employing a person or a fully equipped robot to perform a task is too risky. For example, in a disaster such as an earthquake situation where the terrain is unstable, having heavy machinery working on the area may result in extra damage, which may lead to potential loss of lives and equipment used.

Using a cheaper, lighter agent reduces such risks. Although, it has a huge impact on what the robot can sense, the speed with which the task is accomplished is reduced. The use of multiple agents becomes a natural solution in order to increase the speed, given that a proper division of tasks is made.

Some biologically inspired behaviors are the base for swarm algorithms, such as *Aggregation*, where all robots in the swarm gather. This behavior is essential for self-assembly and formation. [1] proposes a distributed algorithm based on obstacle repulsion forces and robot attraction forces for aggregation.

The opposite behavior of aggregation is the *Dispersion*. [2], [3]and [4] propose repulsion algorithms based on wireless signal intensity only, with [4] having the most successful result in complex areas by virtue of their more elaborate algorithm that takes into account the graph of neighboring robots based on the signal intensities.

The task of collective mapping is a step forward in swarm robotics. Swarm Region Mapping is a relatively unexplored problem. Previous work can be found in [5], which makes use of special robots with precise mapping capabilities along with several basic units. In a different approach, [6] proposes a homogeneous set of robots that can assume different functions, depending on their interaction with neighbours.

Our proposed algorithm for collective region mapping uses a homogeneous set of autonomous robots with similar agent behavior and devoid of a central controller. The agents' global and relative position are unknown at all times.

2 Proposed Work

As the project outcome is the analysis on the mapping capabilities of the unlocalized swarm algorithm, the following setup is proposed.

- A bounded box world with obstacles is considered. For the purposes of the project, it is assumed that the world is static (no moving elements in the world other than the robots).

- Each robot has a relatively simple setup and follows local rules. As there is no centralized control, each individual behavior must work towards the achievement of the global objective (to map the entire environment). The robot has a limited view of the world around it (ability to map a circle of 1 unit around the robot) and a global sense of direction(by means of a compass). Each robot must maintain the ability to build a map from what it perceives and navigate safely. The robot can move in any direction, and its movement will be constrained only by other robots and obstacles in the environment. The robots must exchange maps and merge individual maps when in close proximity.The process of merging maps may be performed by obtaining the relative orientations with which the robots meet.
- The robots will be tuned to move towards unexplored regions and away from other robots (robots move away only after they successfully exchange map information). With this inherent behavior, several exploration techniques will be tested, such as:
  - Raster scan
  - Randomly scan unexplored areas followed by obstacle following
  - Greedy search for large unexplored regions to map
  - Divide population between exploration techniques.
- Since the relative positions of the robots are never known, they do not need to start at the same location.
- The stopping criterion for the algorithm is when a fully bounded map of the world is obtained.
- Another aspect which may be looked into is the possibility of leaving markers on the map when the maps are exchanged. If the robots are unable to find other robots after a specified amount of time, the robot can go to the marked location on the map and wait for other robots which have not found robots to share maps with. Also, they can be used as a homing beacon when the stopping criterion is reached.

3 Proposed Experiments and Expected Outcomes

Once the algorithms are implemented, the relative efficiency of each algorithm will be tested with a standard algorithm like the ant colony optimization. To test the efficiency, each algorithms will be tested on different maps with same number of robots and the same starting positions. Figure 1 contains a representation of a bounded area being mapped by a swarm after some time elapsed.

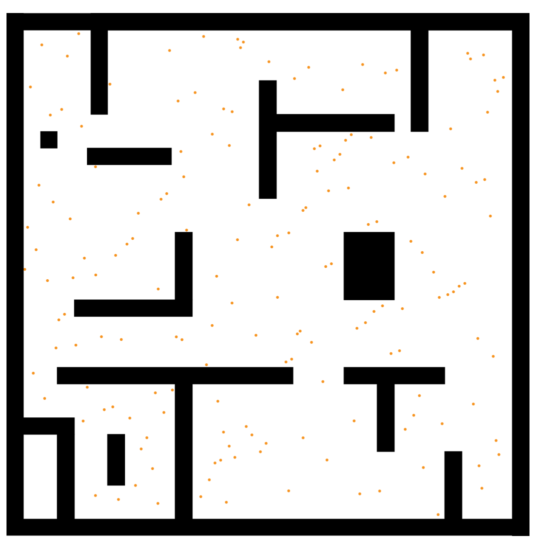

Figure 1: Swarm on bounded area after some time t elapsed.

Our belief is that the algorithm with a divided population of exploration techniques will be the most efficient. We we will also be testing the effect of map size, robot number, and obstacle number on the algorithm efficiency . We believe that increasing the map size will slow down the efficiency exponentially because the robots will have a lesser chance of meeting each other to sharing information. We also believe that the number of robots will increase the efficiency logarithmically because the robots will have a greater chance of exchanging information up to a point where adding more robots will have little to no effect in the performance. Number of obstacles will most likely cause a linear change in efficiency because they merely limit the movement of the robots.

4 Weekly schedule

Week	Tasks
Week 1	- Make World Class - Make Robot Class - Compile Algorithms to Try
Week 2	- Make World Class - Make Robot Class - Compile Algorithms to Try
Week 3	- Integrate Robots into World - Implement Graphics to represent World - Figure out how to implement algorithms
Week 4	- Fix Bugs - Start to implement Algorithms
Week 5	- Experiments with test conditions which include world size, number of robots, and number of obstacles
Week 6	- Tweak parameters - Compare algorithms
Week 7	- Finish and Finalize

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