

Distributed Algorithms to Solve MIS Filling, Mutual Visibility and Uniform Partitioning with Luminous Mobile Robots ¹

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ABSTRACT

The coordination among a large number of autonomous mobile robots, also known as swarm robots, has gained significant interest in recent years. Under the framework of *Look-Compute-Move* cycles, the robots can perform various tasks such as exploration, gathering, pattern formation, dispersion, scattering and others. This thesis mainly deals with three different types of problems using a swarm of autonomous, anonymous and luminous mobile robots. The first problem falls into the class of graph exploration problems where we study the graph filling problem, named *MIS Filling Problem*. For an arbitrary connected graph with specific vertices, called *Doors*, the problem aims to fill the vertices using robots with limited visibility, entering the graph through the Door, such that the set of the occupied vertices forms a maximal independent set (MIS) of the graph. We propose algorithms for two versions of the problem: (1) Single Door under the asynchronous setting and (2) Multiple Doors under the semi-synchronous setting. We also discuss the lower bound for the problem for the single Door case.

The second problem in this thesis is one of the fundamental problems in swarm robotics is the *Mutual Visibility Problem*. This problem is widely studied under various constraints, such as axes agreement, fault tolerance, adversarial schedulers, etc. Opacity is one of the most interesting components in the model, which allows robots to obstruct the line of sight of other robots. The aim of the problem is to achieve a configuration of the robots such that any two robots are visible to each other. We introduce a new flavour to the model where we consider that the robots may exhibit inaccurate movement and have an agreement on one coordinate axis. Inaccuracy is defined as an angular deviation from the robot's target point. More specifically, if the robot r chooses t_r as its target point

¹Title of the Ph.D. Thesis

for the movement, inaccuracy makes the robot, move to a point t'_r such that the distance between r and t_r is the same as the distance between r and t'_r . We propose an algorithm under the semi-synchronous setting, which is optimal with respect to the number of colors. We extend the algorithm for the asynchronous setting using 3 colors. We also examine the problem from the aspect of fault tolerance under the asynchronous setting in addition to the inaccuracy in the robots' movement. All the algorithms under this model take $O(N)$ epochs to achieve the goal, where N is the number of robots. We further discuss the impossibility of the problem for the angular inaccuracy to be greater than 90° .

Another version of the model primarily investigates the mutual visibility problem from the perspective of the mobility failure of the robots with no agreement on the coordinate axes. No axes agreement adds up more challenges in tolerating mobility failure in the context of mutual visibility. We show that the problem becomes unsolvable for a specific initial configuration of the robots under this model where the initial configuration is symmetric. We present an algorithm that tolerates any number of faulty robots when the robots are operating under the fully-synchronous setting. The algorithm runs in $O(N^2)$ rounds. We propose another algorithm in the presence of a single faulty robot that requires only 2 colors in fully-synchronous and 5 colors in the asynchronous setting.

The third type of problem addresses the *Uniform Partitioning* for a given bounded region using a set of N of oblivious mobile robots. We initiate the study of partitioning a region, taking inspiration from our daily life, where our natural tendency is to divide work equally among ourselves to achieve faster results. The problem requires the robots to partition the whole region into sub-regions of equal area, each of which contains exactly one robot. Due to application-oriented motivation, we consider the region to be well-known geometric shapes such as rectangle, square and circle. To the best of our knowledge, this is the first attempt to study the Uniform Partitioning problem using oblivious opaque robots working under asynchronous settings. We propose three algorithms considering three different regions. The algorithms proposed for rectangular and square regions run in $O(N)$ epochs whereas the algorithm for circular regions runs in $O(N^2)$ epochs. The algorithms for the rectangular, square and circular regions require 2 (which is optimal), 5 and 8 colors, respectively.