Abstract

The Terrain Exploration and Coverage problem has been studied in the robotics literature because this problem is a common challenge to many applications such as automatic harvesting, lawn mowing, de-mining, vacuum cleaning, intrusion detection etc. There are several remarkable research attempts, made on Autonomous Mobile Robot (AMR) Terrain Exploration and Coverage problem, based on Genetic Algorithms, Spanning Trees, and Spiral filling paths in the robotics literature. Generally, this research scenario includes tasks that are difficult, tiresome or dangerous for the humans to perform. The use of multiple AMR for solving this problem holds the promise of improved performance over single robot systems and is used to perform a task that is either too difficult or impossible for one robot to perform all alone successfully. Complete and robust terrain exploration and coverage is the problem of driving the footprint of an AMR over all the points of a given terrain in an efficient manner even when there is noise present in actuators and sensors. In Multi-robot Systems, all the robots must be coordinated and this process requires communication, an important factor in distributed multi-robot terrain exploration and coverage. More frequent communication provides more cooperation among robots, and also requires more overall time for the completion of the task. At the same time, less frequent communication slightly speeds up the time for the completion of the task, but creates more problems among robots and increases the risk of failure too.

The aim of this thesis is to formulate an efficient, robust and complete scheme for terrain exploration and coverage problem by using a group of ant-type robots. This thesis presents novel Spanning Tree Coverage (STC)-based schemes such as Simultaneous Multiple Spanning Trees Construction (S-MSTC algorithm) and Extended S-MSTC (ES-MSTC algorithm) using a group of robots to explore and cover the planar bounded environment simultaneously. The proposed schemes are completely distributed and rely on agents having identical controllers that perform coverage of the surface, regardless of the shape of the terrain, by decomposing the terrain into grid cells and constructing multiple spanning trees. The proposed schemes are capable of handling multiple robots, which can divide the area among themselves to achieve a collision-free exploration and coverage. Use of
multi-robot system can accelerate the process of exploration and coverage, thus improves the efficiency, which can be evaluated in terms of area covered over a period of time. These schemes can be used for both indoor and outdoor applications. The range of applications might include tasks such as hazardous waste location and removal, warehouse organization, and human search-and-rescue.

Specifically, we study how the ant-type robots explore and cover the terrain by leaving marks on the terrain, similar to the nature of ants. These marks can be sensed by all robots enabling them to cover the terrain without direct communication with each other. The optimal selection of the number of robots depends highly on the specific task that is being performed and the size of the terrain. We present a simulation study of the proposed schemes, comparing them with the existing algorithms. Several different experiments are being performed by using the Player-Stage simulation platform, in different simulated environments. Experiments involve varying the number of robots to see how the time and success of an exploration and coverage task are affected. Our simulation outputs show that these schemes are more efficient, robust and complete in respect of exploration and coverage than the previous approaches which do not cover partially occupied cells and do not allow multiple robots to move through narrow openings. Also the schemes attempt to spread out its cooperative search, in such a manner that the same area does not get explored and covered again.