Distributed constraint reasoning applied to multi-robot exploration

The research paper provides a briefing of the problems faced in exploring unknown areas by use of multiple robots. Some of the main issues faced during the experiments include robots having to collaborate when spread out on the ground and communicate with each other in order to exchange partial maps and share areas that have not been explored yet. The paper explained the earlier approaches on centralized coordination algorithms and its drawbacks such as the lack of performance of multi robots in speeding up the exploration, idling, performance bottleneck and single point of failure degrade the performance.

The motivation of the whole process is improving the performance of multi robot exploration process. They plan to move towards the boundary between open space and unexplored area. In practice, some robots try to get closer to the boundary but without real cooperation with the rest of the fleet. This article states the concept of frontier-based exploration which has inspired many other works. Main improvements of the frontier-based exploration have helped in achieving higher coordination between robots.

To overcome the drawbacks faced due to the centralized approach, the problem has been redefined as a distributed satisfaction constraint problem. The Asynchronous Backtracking algorithm is used to solve the distributed satisfaction constraint problem. In this approach, each robot is able to choose one from 8 directions for its next move based on three constraints. One is that the future position of the robot must ensure it has at least one accessible robot within its communication range. To maintain connection with each robot, a reference robot is assigned. Every other robot will always be connected with this robot. The second being, to ensure that the future position of robot is not closer to it more than two time the sensor range of robots. The main goal is to prevent the overlapping of exploration processes. The third is that the robot must choose a direction such that the distance between it and the frontier is minimized. Here, the algorithm consists of repeating sequence of updating maps and connectivity tables for each robot, and constructing the distributed CSP based on connectivity tables and current positions of robots, order the value of each domain taking the distance to the frontier into account and solve the distributed CSP to obtain future directions of each robot. Under these constraints each robot will continue to explore until there are no more frontiers.

The paper explains an implementation of the algorithm in NetLogo which is a multi-agent programmable modeling environment. A tiny period of time has been given for each robot to transfer from current position to the future position. Then the robot is given another tiny period of time to decide the next direction. This minute time should not be too small or too large. Here, the environment is modelled in a two dimensional structure. In simulations, the environments with different levels of complexity which depend on the shape of the obstacles and the size of the obstacles are tested. It could be observed that robots explore faster in simple environments. Adding more robots improves the efficiency while having extra robots create many interferences which degrades the overall performance. The robots having different communication ranges (Wi-Fi) have been tested and it has been observed that the increased communication range helps to improve performance of robots.

By considering the facts supplied, the current solution given seems to be more productive than a centralized approach. In a centralized scenario, the central node has to perform tasks with heavy load, calculations and provide a target to the agents. But the distributed CSP approach shares the tasks and calculations among all the agents. All the agents have to calculate and suggest the target confirming to their own constraints. However, issues could arise as all the agents will need to have the same level of computational power in order to provide the optimal exploration and communication process. Provided that the agents have the same power the distributed CSP provides a more cost effective and an optimal solution to the problem.