Motion Planning Application- Collaborative Coverage Path Planning

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As I had alluded to earlier in my introduction, I found the idea of multiple robots collaborating to map a large region quite interesting. It can have multiple applications in the areas of swarm of quadrotors exploring a new terrain, a group of vacuum cleaning Roombas covering a large house, delivery robots etc. One of the fanciful applications could be of using multiple smaller sized rovers for planetary explorations.

First before learning about the collaborative applications, it is important to see how coverage path planning is done by a single rover. A critical task in achieving rover autonomy is automatic route planning between a landing site and operations sites. To date, path planning research for planetary rovers has focused on the problem of navigating locally through fields of rock obstacles en route to a global position goal, over tens of meters. But these navigation distances are increasing quickly. When it comes to large range navigation, challenges such as variable lighting, communications moving around obstacles and most importantly resource management such as battery power come into play.

One paper which addresses this issue is:
https://www.ri.cmu.edu/pub_files/pub4/tompkins_paul_2004_3/tompkins_paul_2004_3.pdf (Global Path Planning for Mars Rover Exploration).

The global path planning problem is multi-faceted - ideally it calls for a solution that solves for optimal trajectories through spatial, temporal and resource dimensions. Furthermore, an algorithm operating under the uncertainty of planetary exploration must have the ability to efficiently re-plan as a robot gains new information about its environment.
To this end the authors have developed a novel search algorithm called Incremental Search Engine(ISE) with a high-level search strategy to find optimal plans. ISE is a graph-theory based, heuristic search algorithm optimized for planning and re-planning in high-dimensional spaces. ISE is fundamentally very similar to A-star , just that it

performs better with multiple constraints as well re-plans faster than A-star in case of situations where the rover will have to re-plan, such as hitting a dead end.

Next, comes the idea of using multiple rovers to explore an area. I think the paper: https://www.mdpi.com/1424-8220/21/11/3709 (Collaborative Complete Coverage and Path Planning for Multi-Robot Exploration) is a good paper which addresses this topic. As per the authors, the difficulties usually lie on the real-time communication and online decision-making among the mobile robots. To cope with the complete coverage and path planning for multiple agents, one approach is to modify the efficient algorithms studied for a single robot to the multi-robot collaboration. As such, the algorithm consists of selecting a goal and then choosing a good cost function which makes sure the robot doesn't get too close to the obstacle and generate a path by optimizing the cost function. In multi robot case exploration method adopts the individual decision rules for the robots, and shares the same environment map via the online communication to minimize the coverage overlap. And in this manner the entire area is covered.

I think the ideas of both these papers can be used to come up with solutions to problem of planetary exploration using multi robot systems, which would be not only quite cool, but also makes the possibility of the exploration tasks more fruitful, as the dependence on just one rover is gone.