SEND IN THE DRONES

The Versatile Applications of a Multi-Robot Coverage Control Framework

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Imagine a team of robots and autonomous vehicles scanning an area for a shared objective—whether for rescue missions, wildlife observation, or making warehouse operations more efficient. ***Rachael Duca****'s Ph.D. research, supervised by* ***Dr Ing. Marvin Bugeja****, is building a framework for these high-tech gadgets to operate effectively.* **THINK** *looks into how this smart system of robot collaboration works.*

ng. Rachael Duca is developing a highly mathematical framework. Her number-crunching algorithms help manage a multi-robot operation. Teams commanding these robots can rest assured that deploying such a multi-faceted army will be a walk in the park thanks to the mathematical magic under the hood! This sophisticated autonomous system considers the environments the robots are scanning as well as their sensor and battery capabilities, allowing the robots to address specific tasks such as search and rescue, wildlife observation, or warehouse management, intelligently.

The researchers' approach is practical, robust, and features fault-tolerance elements. The framework can adjust the robots' behaviour to situational changes during the coverage process. 'It allows reassigning the robots in case of faults, changes in the errands or areas, and other factors that alter the optimal allocation solution,' Duca says. Designed to operate as self-contained modules, the robots' individual needs are met through an efficient and intelligent control system.

ALWAYS JUICED UP

Several factors come into play when allocating a task for a team of robots. For instance, a robotic team has finite energy. As many different types of robots may be involved, the team of robots is heterogeneous, meaning that all these robots have different energy needs, sensing facilities, and even physical structure. All these factors render the optimisation process of the coverage control problem more challenging.

'Additionally, the robots have different actuator capabilities. If one robot is faster, the system needs to assign it with a bigger area to cover,' Duca says. Her framework considers all these critical factors when controlling autonomous robots for mapping an area. 'The framework weighs how to allocate robots to specific areas within the environment, as there can be different areas of importance,' she adds. These areas may also be of different natures, such as shorelines or the sea. Autonomous robots and remotely operated vehicles must be assigned tasks appropriate for their capabilities regarding the scanning environment.

'Imagine a scenario where someone has been lost at sea,' Dr Ing. Marvin K Bugeja, the supervisor of Duca's Ph.D. project and Senior Lecturer with the Department of Systems & Control Engineering, says. 'A team of people is utilising different technologies to search the area. The framework Rachael has been working on helps the rescue teams to cooperate on planning the coverage control of the area, considering the different types of mapping and scanning vehicles, and then manage the scanning itself autonomously. It is simply a very good example of how artificial intelligence can help us solve very complex problems better and quicker.'

COVERAGE CONTROL STAGES

The framework rests on three stages for coverage control. The first stage is determining the location the robots will work on, in order to sort out the allocation problem. The main focus here is what happens when a robot, for some reason, falls out of the search. 'If a robot is out, for instance due to lack of energy, we face a coverage problem again with the remaining robots. The question arises: How will we solve the problem in real time with the remaining agents?' Duca says.

The second stage is environment segmentation. 'Here we look into the size and terrain of the search area to make sure we can determine a robot's performance relating to their energy levels, speed, and capabilities,' Duca says. This optimisation process involves segmenting and dividing the environment into pieces, each belonging to a particular agent for them to cover.

The third stage of the problem concerns the controller. 'How are we going to drive the robots towards these areas in a fast and energy-efficient manner? When we deploy robots, they will start from one particular location and must arrive at the designated search location,' Duca says. The robots need a controller that takes care of this process to ensure their energy is not depleted too quickly, meaning they must go to a charging depot and thus fail to complete the task.

Duca's framework can focus on an area of preference, even if it is moving, such as a school of jellyfish being transported by currents. The framework monitors the movement and, utilising a mathematical model, can help forecast how the area of preference shall move to support appropriate tracking.

POTENTIAL USES

But what are the potential uses once the framework is ready for rollout? The industries it could go into are many.

'We talked to a marine biologist at one stage, which has shown us that a potential and possible application of this framework could be to have a team of robots gathering samples from nature or monitoring species on the move,' Duca says.

Another potential venue would be to use the framework in an industrial environment, such as a vast warehouse. Amazon already uses autonomous robots in its depositories. The framework could be utilised to help control those warehouse robots and optimise area coverage and tasks.

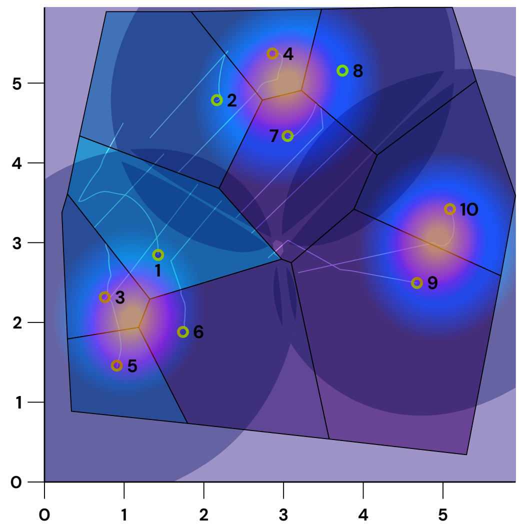
Efficiently covering an environment is useful and necessary in various applications such as surveillance or search and rescue. Such settings may present challenges like multiple, distinct areas, some with higher importance than others in the same environment. The robots in the team may be heterogeneous in their type and sensor capabilities, and hence must be optimally allocated to different areas according to their abilities.

These areas may also be time-varying. Hence the robots in a team must track the changes in these areas throuh time. Furthermore, the robots in the group may have actuator and battery constraints that must be accounted for in the algorithm.

'In our research, we are developing an optimisation framework that allows a multi-robot team to cover an environment with multiple, distinct areas of interest, which are time-varying, when the agent is subject to energy and sensor constraints. This framework is a modular framework that allows different algorithms to address specific tasks, solved in the framework towards an efficient and effective coverage control solution,' Duca concludes.

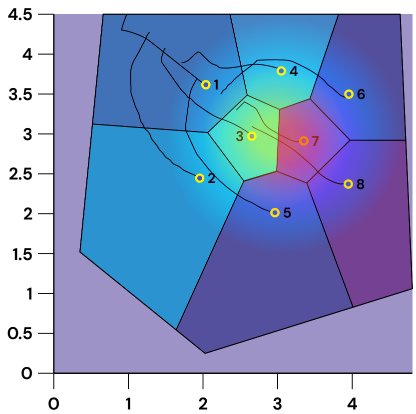
Looking ahead, the potential uses of this framework are virtually limitless. From assisting marine biologists in gathering samples and monitoring species to optimising tasks in vast warehouses like those employed by Amazon, this framework promises to revolutionise a myriad of industries. Duca's highly mathematical multi-robot coverage framework contributes immensely to the advancement of robotics and autonomous systems. As this revolutionary technology advances, it promises to enhance collaboration among robots and optimise efficiency across diverse applications, leading us toward a future where autonomous systems seamlessly work together to accomplish shared objectives with precision and reliability.

o = Robots, + = Goals, Iteration 30



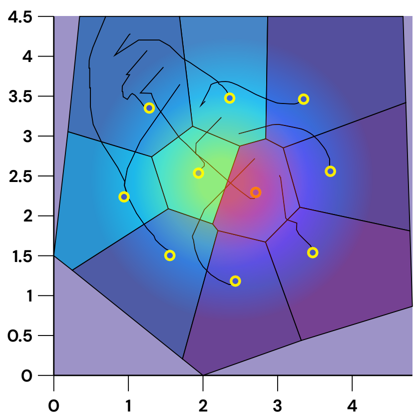
Sub-teams from the whole multi-robot team covering each individual area of higher importance. The reddish/orange areas are called 'Areas of Higher Importance.' These represent a high probability of some event happening in that area. The whole team of robots needs to coordinate among itself to 'send' the appropriate robots to each of these areas, depending on the capabilities of the robots themselves.

o = Robots, + = Goals, Iteration 50



The final coverage configuration of the multi-robot team as it hovers around the area of higher importance in the environment. Similar to the image above, except this time, there is only one area of higher importance in the given environment.

o = Robots, + = Goals, Iteration 40



An alternative iteration in which the area of importance has been moved slightly.

Diagrams adapted for ***THINK*** *Magazine courtesy of Ing. Rachael Duca*