Self-Organizing Mesh Networks of Search & Rescue Drone Swarms

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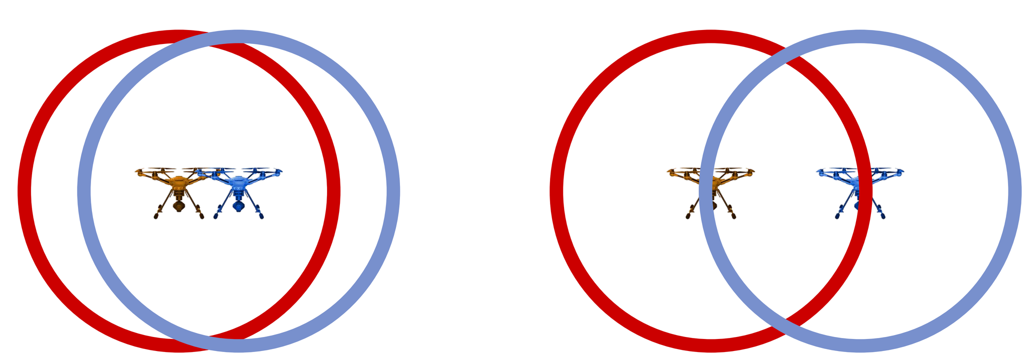
Introduction

In emergency situations, rather than risking the lives of human rescuers, it would be safer to use intelligent drone swarms to search disaster areas (such as wildfires or explosion aftermaths). Wireless communication is an important component of drone swarms because many other components rely on it. Creating a swarm to organize their drone networks autonomously would further the technology of saving lives [1].

Research Goals

Our research focus is to give each drone within a swarm the ability to self-organize itself with focus on:

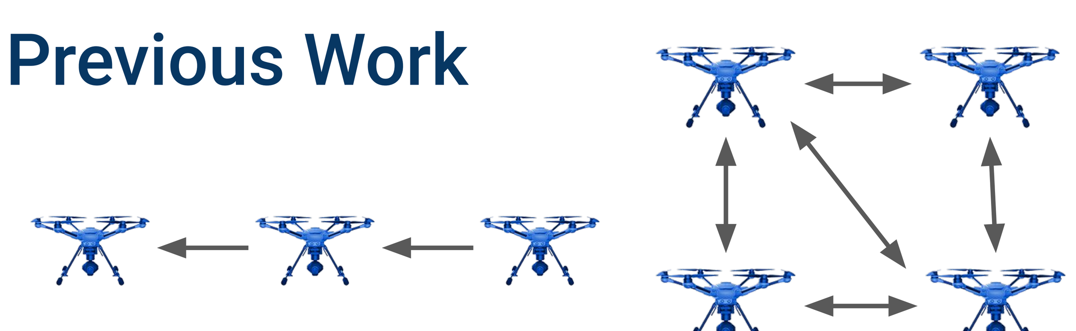
- maximizing search area
- maintaining wireless intercommunication.



Non-optimized Spread   Optimized Spread

The rings represent the drones' range of communication. If drones are too close, they are not maximizing the search area that they could achieve. A swarm should maintain this spread as it travels.

Previous Work



Limits of Old System   Possibilities with New System

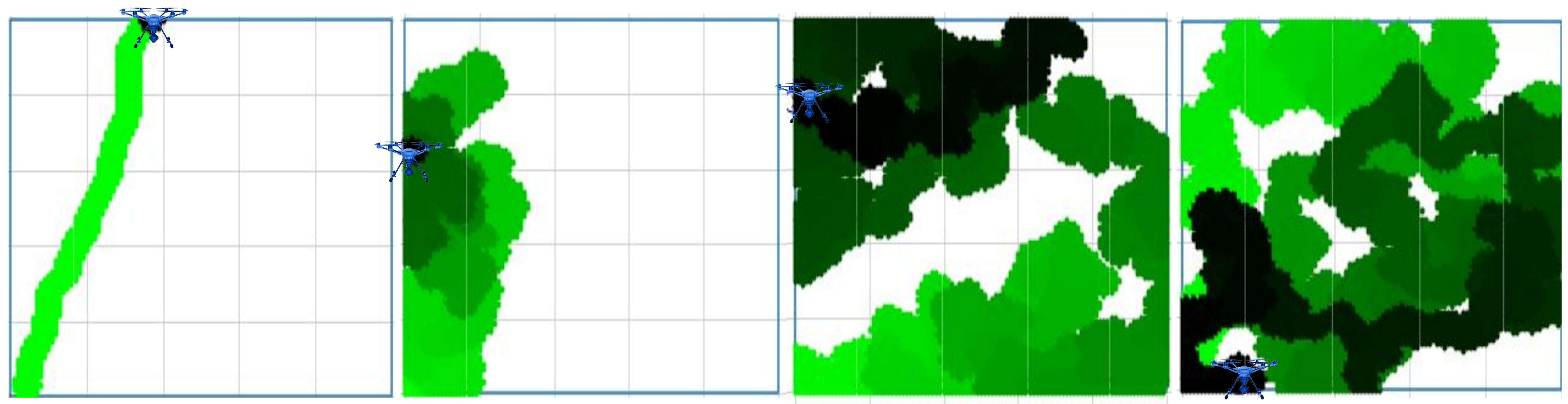
A previous system [2] enables drones to rely on another drone for positioning. Our work adds support for drones to rely on more than one drone, which means support for more swarm configurations. The arrows point from a drone to the drone that it relies on.

Methods

Real-world implementations can introduce many variables, such as wind or poor-precision motors. In order to avoid these complications, this algorithm was created and tested in a simulation. After a system is implemented and tested in this ideal environment, future work will be to implement it with real-world drones.

Each simulated drone has its own *neural network* (NN). Each NN receives inputs such as the drone's positioning and communication strength with its neighbors. The NN then outputs a direction for the drone to move to attempt to improve the *fitness* of the swarm. The *fitness* of the swarm is the metric of how well the swarm performs. A *genetic algorithm* (GA) makes adjustments to the NN's values in hopes of improving it.

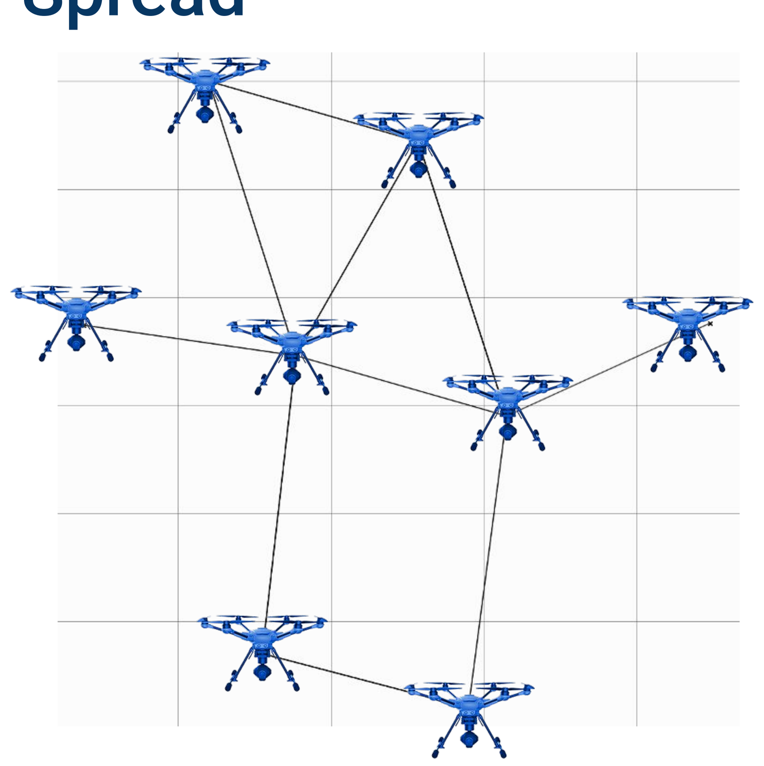
Area Search



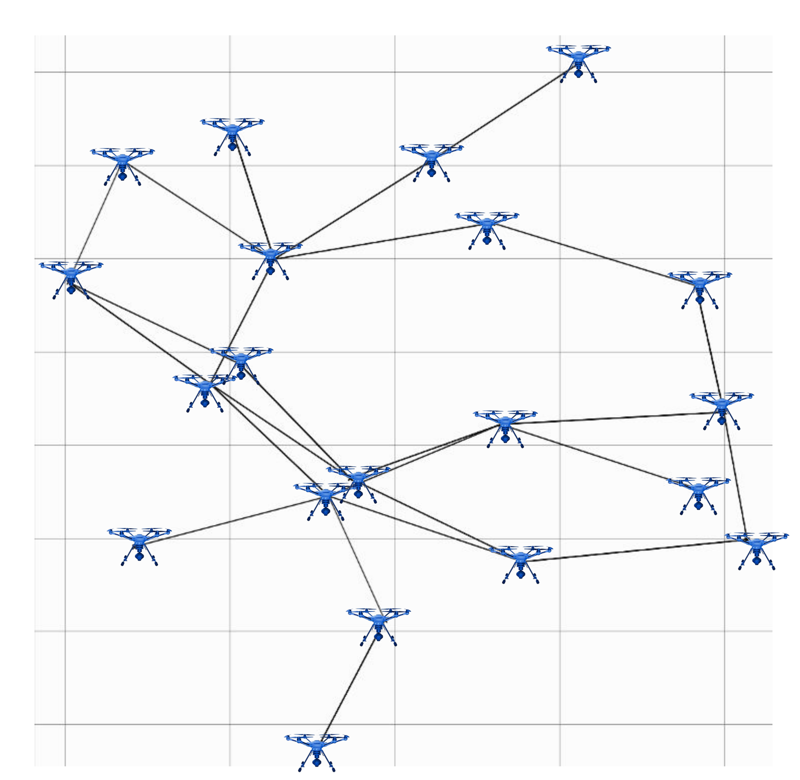
Generation 1   Generation 22   Generation 92   Generation 343

Shown above is one run of a simulated drone over many generations. The max area searched was *80.43%*, which is typical for this algorithm. The drone is simulated for the same amount of time each generation, and survives if it covers more area than the previously fittest drone [3]. The lighter green represents earlier in the path, and the darker is later on. This correlates to the battery life of the drone over time.

Spread



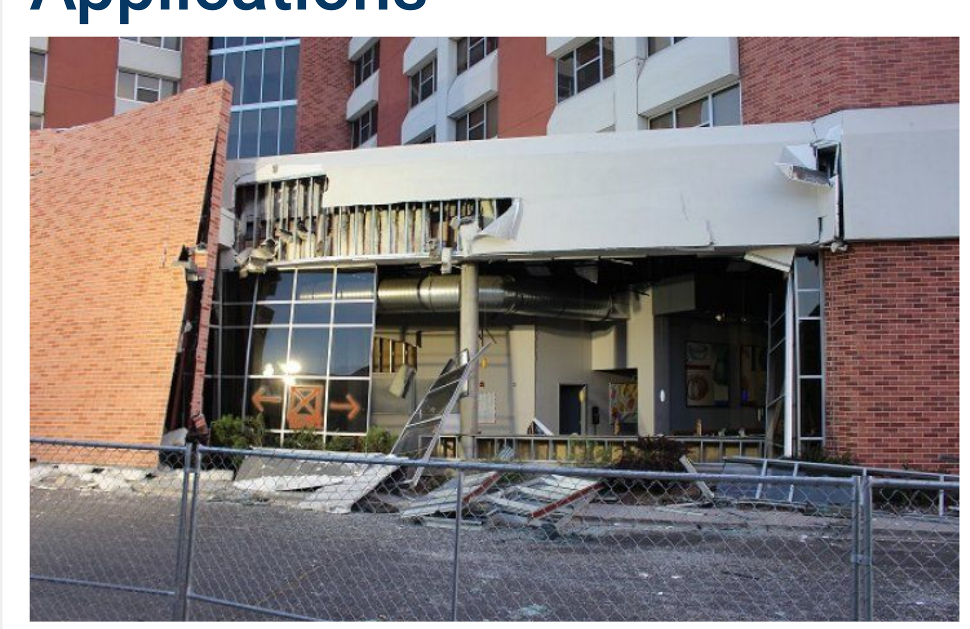
Results with 8 drones



Results with 20 drones

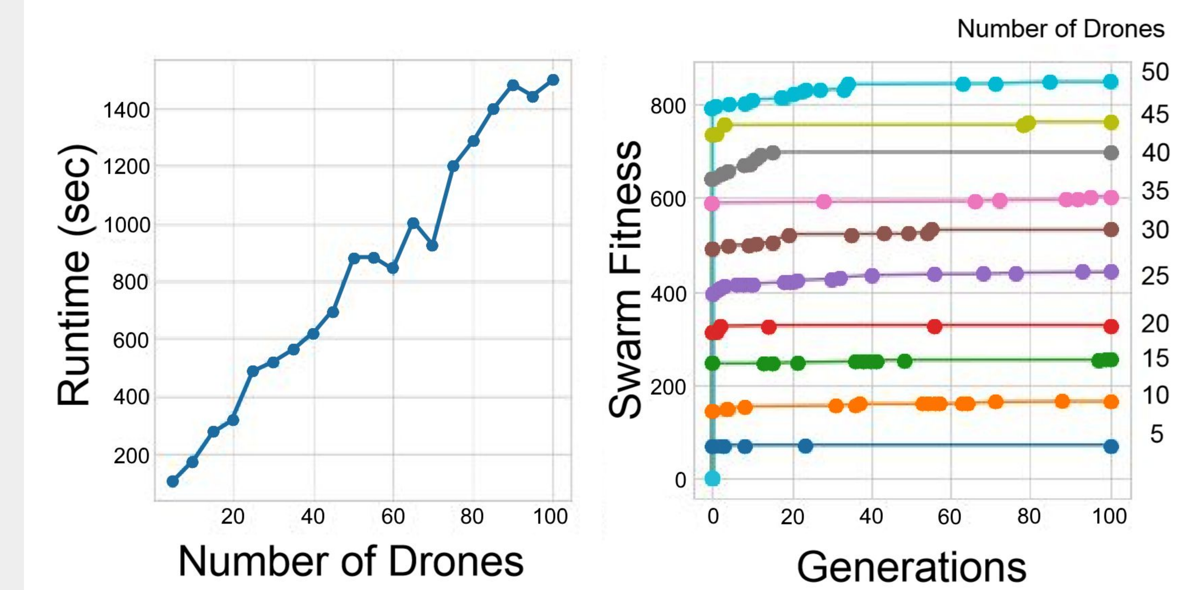
The lines show how the drones are connected (which drones rely on each other) [4]. Some drones still end up close together due to not seeing drones that they do not rely on. Future work will enable the drones to change their reliance structure mid-flight.

Applications



Firefighters at the Argenta Hall explosion entered the building without realizing the extent of the damage, and they quickly realized that it was unsafe. If drones could be used to search for the safest path beforehand, their risk would be minimized.

Results



Left graph: The simulator was run for 300 generations with different numbers of drones. There is a linear correlation between runtime and number of drones.
Right graph: *Fitness* improves at a logarithmic rate. Each line is a different drone count. Each dot is a new best solution. There is no clear correlation between drone count and the rate of finding solutions.

Conclusions and Future Work

Emergency situations need code to run as quickly as possible. This method works faster for spreading out a swarm rather than searching an area, but both can be improved. Possible future fixes to runtime include:

- Each swarm gets one shared *neural network* instead of each drone getting their own
- Using *Reinforcement Learning* instead of *Genetic Algorithms*
- Run simulation across multiple computers

Future work will also include combining travel and spread functionality, as well as a practical implementation of this system.

References

[1] V. Lomonaco , A. Trotta , M. Ziosi , J. D. Y. Ávila, N. Díaz-Rodríguez, *Intelligent Drone Swarm for Search and Rescue Operations at Sea,* CoRR, 2018.
[2]T. Brodeur, P. Regis, D. Feil-Seifer, and S. Sengupta, *Search and Rescue Operations with Mesh Networked Robots,* Proceedings - International Conference on Computer Communications and Networks, November 2018.
[3] A. Majd, A. Ashraf, E. Troubitsyna and M. Daneshtalab, "Integrating Learning, Optimization, and Prediction for Efficient Navigation of Swarms of Drones," 2018 26th Euromicro International Conference on Parallel, Distributed and Network-based Processing (PDP), Cambridge, 2018, pp 101-108.
[4] Marco Di Felice, Angelo Trotta, Luca Bedogn, Kaushik Roy Chowdhury, Luciano Bononi, *Self-Organizing Aerial Mesh Networks for Emergency Communication*

Acknowledgements

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