Section IV: Discussion

The results of the study reveal valuable insights into the performance of the integrated drone navigation system across varying obstacle densities. In the single drone instance, there is a clear correlation between obstacle density and both completion time and energy consumption. As obstacle density increased, the mean completion time exhibited a consistent 0.515-second increase for every 1% rise in obstacle density (R^2=0.99). Similarly, the average energy consumption demonstrated a 0.339 J increase for each 1% increment in obstacle density (R^2=0.982). These findings give insight into real word applications for the proposed algorithm. The suggested algorithm also has an equal measured energy consumption with the "Square Pattern" (Andersen, 2014).

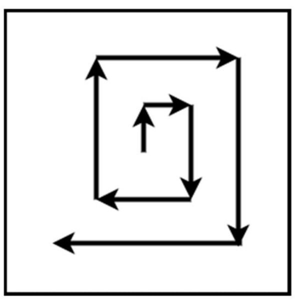

Figure 14: Expanding square search pattern (Fevgas et al., 2022). Depiction of the square pattern. Using the experimental energy constants used in this paper, the energy consumption can be measure to be 8.3 J which is the same as the energy consumption of both the single drone and the double drone instance in an environment with no obstacles.

Transitioning to the double drone instance, the examination of total energy consumption for both drones combined further highlighted the influence of obstacle density. The linear regression analysis revealed a 0.333 J increase in total energy consumption for every 1% increase in obstacle density (R^2=0.931). Simultaneously, the completion time for the double drone instance exhibited a 0.32-second increase for each 1% rise in obstacle density (R^2=0.976). This response of the collaborative system, both in terms of completion time and energy efficiency, provides insight into their potential real word applications.

The comparison between single and double drone instances reveals advantages of collaborative navigation in obstacle-rich environments. In the single drone scenario, the mean completion times increased proportionally with increasing obstacle densities. While the mean completion time increased in the double drone scenario as well, the competition time of the entire algorithm was on average 37.8% less than the single drone instance clearly pointing out the advantages of collaborative navigation in high-obstacle areas.

Current path planning algorithms do not perform on real time environments. This project, while has some pitfalls, addresses the problem of realtime mapping, obstacle detection and area assignment for faster coverage paths which are extremely crucial to search and rescue missions.

Limitations

The proposed methodology relied on properties of integral numbers in certain cases. These might not cover all cases and may not apply to real life scenarios (Appendix A). The model also has an unnecessary time complexity. The drone might not need to plan and assign paths that are far away while focusing on its immediate surroundings, thus conserving memory and computation power. The experimental values of energy consumption are derived in “UB-ANC planner: Energy efficient coverage path planning with multiple drones” (Modares et al., 2017). While these constants are applicable to the drone presented in their paper, these constants have to be experimentally measured for each drone.

Future works

Future works involve constructing a physical drone and implementing this algorithm in a physical environment. In addition to that, advanced communication protocols could be incorporated between the drones for better coordinated movement.

Section V: Conclusion

In conclusion, this project addressed the limitations of current search and rescue drones by proposing a collaborative navigation system with a focus on energy-efficient path planning. The objectives, ranging from obstacle avoidance to optimal area division and energy-aware coverage path generation, were systematically tackled using simulation and algorithmic implementations.

The methodology involved the integration of ultrasonic sensors, LiDAR sensors, and energy efficient path planning algorithms to create a comprehensive drone navigation system. The energy-aware coverage path generation utilized modified Minimum Spanning Trees (MST) with an added energy cost to ensure thorough coverage while minimizing energy consumption. Results from single and double drone instances in varying obstacle densities demonstrated the effectiveness of the proposed algorithm. The algorithm also highlighted the advantages of collaborative navigation in high-obstacle environments, with the double drone scenario showing a notable reduction in completion time compared to the single drone instance. However, certain limitations, such as reliance on integral numbers in specific cases and unnecessary time complexity, were acknowledged. Future works should focus on implementing the algorithm in physical environments and exploring advanced communication protocols for enhanced drone coordination.