Implementation of a Turtle-Based Consensus Algorithm on Drone Swarm Search & Rescue

Jack Capuano[1] | Austen Pallen[2] | Grace Gratton[2] | Dr. Bryan Watson[1]

1. *Embry-Riddle Aeronautical University Electrical Engineering and Computer Science Department*
2. *Embry-Riddle Aeronautical University Physical Sciences Department*

Abstract

The use of swarms such as unmanned aerial vehicles to solve problems is becoming more prevalent around the world. One promising application is drones in Search & Rescue operations. The modeling and simulation of these scenarios could improve the success rate and efficiency of those operations and in the case of Search and Rescue, help save lives. **Our research question is: How can a turtle-based consensus algorithm be implemented into drone swarm search patterns to increase the success rate of Search and Rescue?** Using a previously created testbed that serves as a model of drone swarm Search and Rescue operations under variable conditions, a turtle-based consensus algorithm will be implemented into the drone swarm searching patterns. **We hypothesize that implementing a turtle-based consensus algorithm for Drone Search and Rescue could increase the success rate of critical systems with a minimal decrease in the efficiency of the main task.** A total of 7,150 simulations with a range of 0-100% faulted agents were run between four separate algorithms. The average success rates of each algorithm was then compared. 4 Drone verification performed best during 0-60% faulted agents. However, the turtle-based algorithm performed an average of 3.35% better than 4 Drone Verification during 75-85% faulted agents. When compared to no verification, it had an average of 14.50% higher success rate.

Purpose

- Gap: Drone swarms are the future of Search and Rescue. However, current systems are inefficient, may miss targets, and could be negatively impacted by faulted agents
- **The implementation of a turtle-based hatching consensus algorithm on drone search patterns could increase success rates by reducing the impact of faulted agents, directly saving lives**
- Faulted agents (nonworking drones) could cause failure to recover the target thus reducing their effect is a priority, however this will increase the time to find the target
- Why it matters: Improving search and rescue systems will save the lives of individuals likely in distress and in dangerous environments

Methods

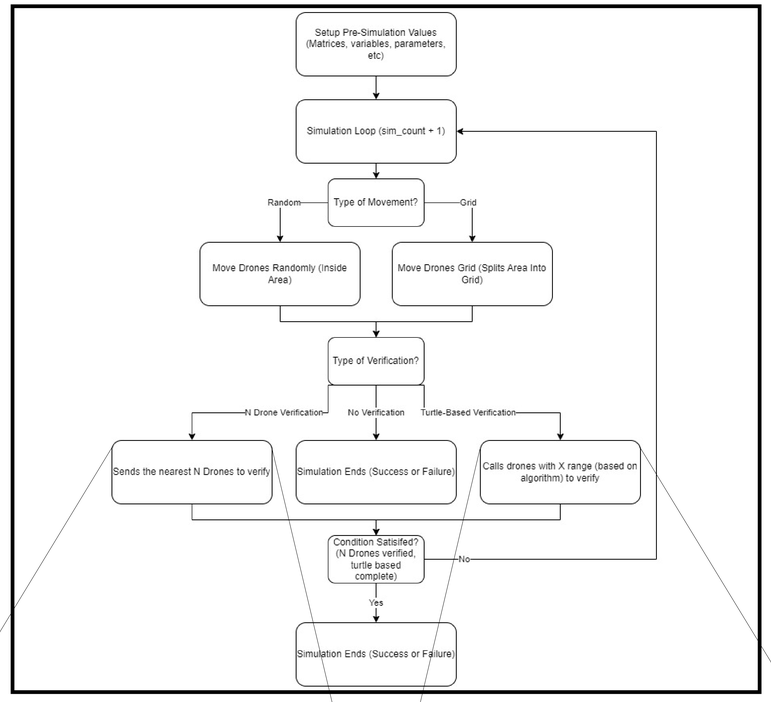
- Drone swarm search and rescue model used as a testbed
- Experiments included testing the efficiency/success rate of consensus algorithms (No verification, N Drone verification, Turtle based)
- Simulations run in MATLAB
- 50-1000 runs per faulted agent % for all four methods of verification
- 500+ LOC, 7,150+ total runs

Drone Search and Rescue Testbed

- Simulates drone swarm operations under dynamic environmental conditions.
- Model features include:
  - Drones searching for a target
  - Changeable parameters (such as # of drones, drone speed, search patterns, etc.)
  - Consensus Algorithm verification for potential finds

Design Process Flowchart

Figure 1: Drone search and rescue simulation design process flowchart



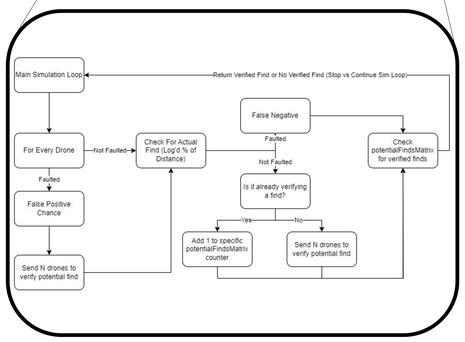


Figure 2: N Drone Verification logic for a single drone. 2 or 4 drones must verify location of target.

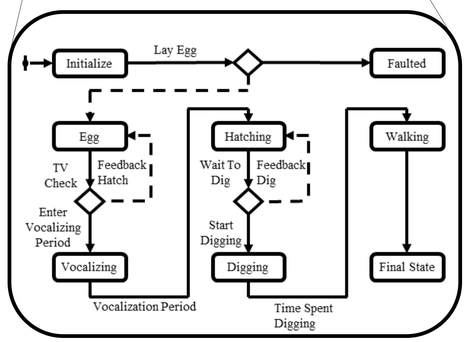


Figure 3: Turtle-Based logic for a single drone. Lines represent transitions between states, shown as boxes. Dashed lines represent feedback, which will loop until consensus is reached on that condition.

Turtle-Based Consensus Algorithm

- Agent-Based ANYLOGIC model
- Agents (turtles) attempt to achieve 66% consensus to hatch
- Failure to reach consensus within time limit leads to 'death' of the agents
- Tested against 0, 5, 10, 15, and 20% faulted agents
- Agents achieved consensus with coefficients of variance of 2.1%.

Results

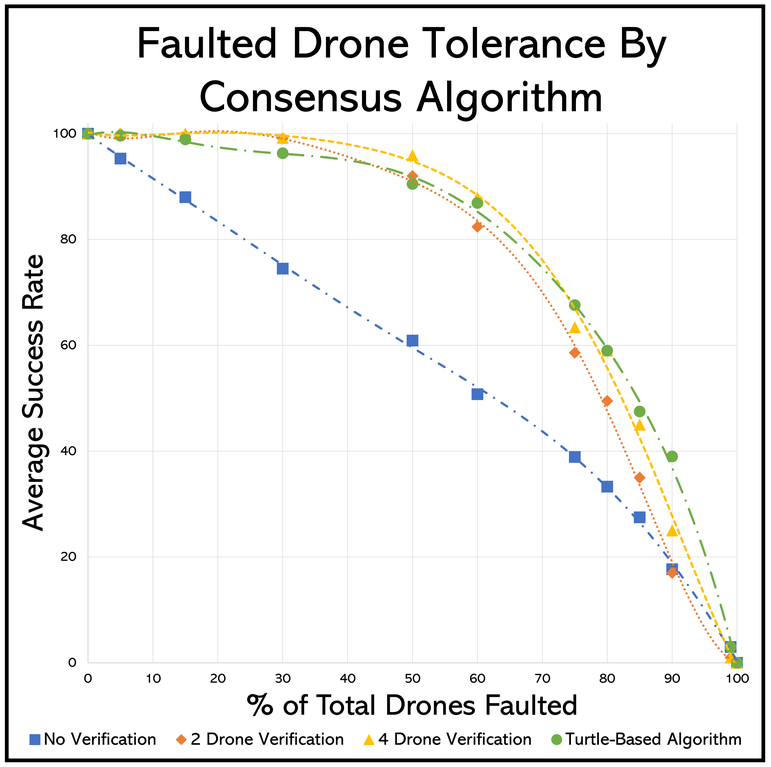


Figure 4: Average Success Rate (y) of the drone swarm identifying a target with some % of faulted drones (x) for four methods of verifying the target.

Conclusion

- Turtle-based consensus algorithm is more resilient to faulted agents than other verification methods
- Average success rate increased by 5.18% compared to 4 Drone Verification during 75-90% faulted drones
- 16.54% more successful than no verification algorithm
- Average time to find target was 12.90 hours
- Average time to find target was .48 hours less than 2 Drone Verification

Biologically Inspired Design-for-Resilience Lab

Contacts

Jack Capuano: capuanoj@my.erau.edu
Austen Pallen: pallena@my.erau.edu
Grace Gratton: grattong@my.erau.edu
Dr. Bryan Watson: watsonb3@erau.edu

Citations

- Pallen, A. & Watson, B. A New Multi-Agent System Consensus Algorithm Inspired by Synchronous Turtle Hatching Behavior. Conference on Systems Engineering Research (In Press 2024).

Future Work

- Implement and test standard consensus algorithm on testbed
- Correcting the analog between turtle-based consensus algorithm to drone swarm
- Journal paper submitted to IEEE Transactions on Cybernetics in July