Search and Rescue Drone Flocking for Efficient Emergency Response

Application Domain

The primary purpose of this drone flock is to aid in search and rescue missions. In large-scale disaster scenarios, such as earthquakes, floods, or forest fires, these drones can quickly cover large areas, locate survivors, and deliver aid. The initial phase involves the drones traveling in a large flock to the search area. Once they arrive, they split into smaller groups, each searching different sections to maximize coverage efficiently and reduce the time it takes to find those in need of assistance.

Justification on The Chosen Flock Drones

This type of flocking system was chosen because travel in groups, enabling efficient travel over long distances while maintaining flexibility. When the drones arrive at the target area, they split into smaller flocks, allowing them to cover different sections of the area thoroughly.

Search and rescue drones are particularly useful in emergency situations such as natural disasters, where they can be deployed rapidly and reach areas that are difficult or dangerous for human responders. They help to locate survivors, assess damage, and even deliver supplies, significantly speeding up rescue efforts while minimizing risks to rescue workers. These drones are equipped with sensors like thermal cameras, GPS, and object detection, making them capable of operating in challenging environments like dense forests, rubble, or flood zones. Their ability to search vast areas while maintaining elevated levels of precision makes them an essential tool for modern emergency response.

Summary of Drone Behavior and Functionality

The drones are designed to operate as a cohesive flock using a **centered flock behavior** that integrates multiple behavioral components:

- **Cohesion:** Keeps drones close to their neighbors.
- **Alignment:** Ensures that they align their movement direction with the group.
- **Avoidance:** Prevents collisions by maintaining a safe distance.
- **Stay in Radius:** Keeps the drones within a certain boundary around the target area.

Visual Feedback and Victim Interaction:

- The drones change color from white to red based on their proximity to nearby objects or other drones. This color transition is a visual cue indicating their level of interaction or awareness of their surroundings.

- When a drone finds a "victim" (a target point randomly placed within the scene), it changes color, stops moving, and marks the victim's location as discovered, ensuring other drones ignore this spot in future checks.

Key Functions Added

Here are the critical functions that were integrated into the code to support these behaviors:

1. **PartitionDronesBasedOnVictims() Function:**
    a. This function performs an O(N) partitioning of the drones into two sublists based on their interaction with victims.
    b. Drones are categorized as either actively searching or stopped at a victim's location.
    c. Ensures that once a victim is found by one drone, other drones do not waste time investigating the same location.
2. **Victim Generation Function:**
    a. Places victims at random positions within the expanded scene size (50 units), with each victim spaced apart to avoid clustering.
    b. Sets the number of victims to be 10% of the total number of drones, ensuring a balanced distribution.
3. **Performance Measurement:**
    a. A **Stopwatch** is used to measure the execution time of the partition function, and the average time taken is calculated.
    b. The average execution time is logged to the Unity console every 60 frames to help analyze the performance impact of the partitioning logic.
4. **FPS Display and Average Time Calculation:**
    a. An FPS counter was added to display the current frame rate.
    b. The average execution time of the partition function is calculated and displayed in the Unity console for performance tracking.

Updated Drone Behavior and Visual Cues

- **Color Transition:** The drones start with a neutral color (white) and gradually turn red as they sense other drones nearby, indicating increasing levels of interaction.
- **Victim Response:** Upon discovering a victim, the drone changes color to visually signify its status and remains stationary at that location.
- **Group Dynamics:** As long as the drones are moving towards the search area, they follow the centered flock behavior to ensure they travel as a unified group, only splitting up when they reach the target zone.

This approach combines intelligent group movement with real-time visual feedback, making the drone swarm more efficient in search and rescue missions while also providing clear indicators of each drone's status and performance.

Centered Flock Behavior

Centered flock behaviour is a composite approach that balances several key behaviours to ensure that the drone swarm operates effectively as a cohesive unit. This behaviour integrates multiple factors with specific weights, optimizing how the group moves and interacts:

1. **Cohesion (Weight: 4)**: Cohesion plays the most significant role in this behaviour, encouraging each drone to stay close to its neighbouring drones. This focus on cohesion helps maintain the structural integrity of the group as they move towards their destination, reducing the risk of individual drones straying off course. This ensures that the drones reach the target area efficiently and without unnecessary fragmentation.
2. **Alignment (Weight: 1)**: Alignment helps the drones synchronize their direction of travel. While not as strong as cohesion, alignment allows the drones to adjust their headings slightly to match the average direction of the group. This supports smoother and more unified movement, reducing chaotic or erratic paths that could slow down the journey.
3. **Avoidance (Weight: 2)**: Avoidance ensures that the drones maintain a safe distance from each other to prevent collisions. With a moderate weight, avoidance strikes a balance between maintaining close proximity for cohesion and keeping enough distance to prevent interference or crashes, especially in congested scenarios.
4. **Stay in Radius (Weight: 0.1)**: Staying within a defined radius is a subtle guiding force in this behavior, encouraging the drones to remain near a central point or area of interest. Although its influence is minimal compared to the other factors, it helps to gently steer the flock toward the designated search zone or target area, ensuring that no drone drifts too far away from the mission's focal point.

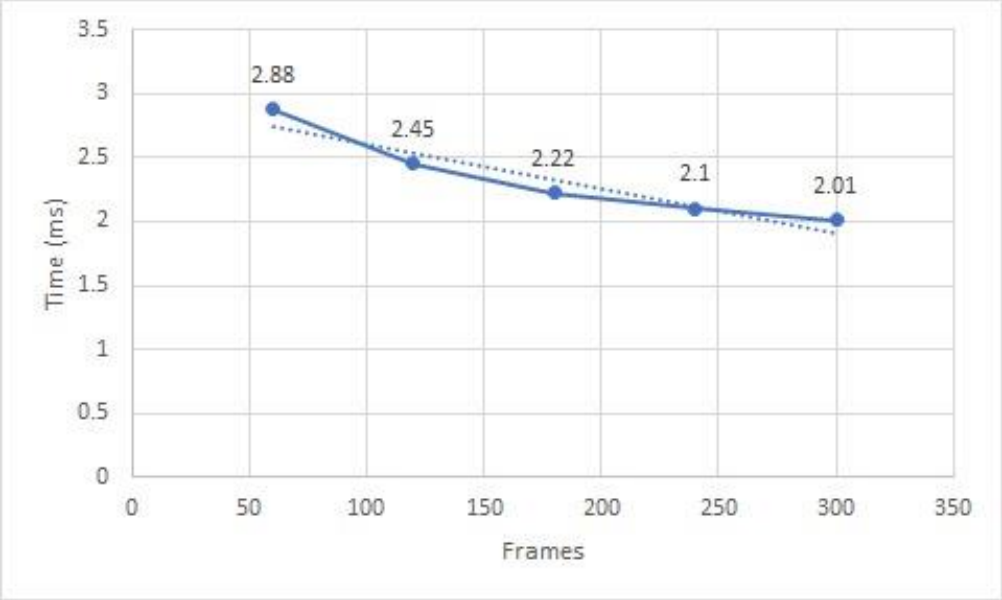
Purpose and Advantages

Centered flock behavior is essential for the initial phase when the drones are traveling to the search area. By emphasizing cohesion, the group remains tightly knit, minimizing delays or inefficiencies during transit. The alignment component ensures that the movement remains coordinated, while avoidance prevents accidental collisions that could disrupt the formation. The small influence of staying within a radius helps the flock remain focused on reaching the target area as a unified entity.

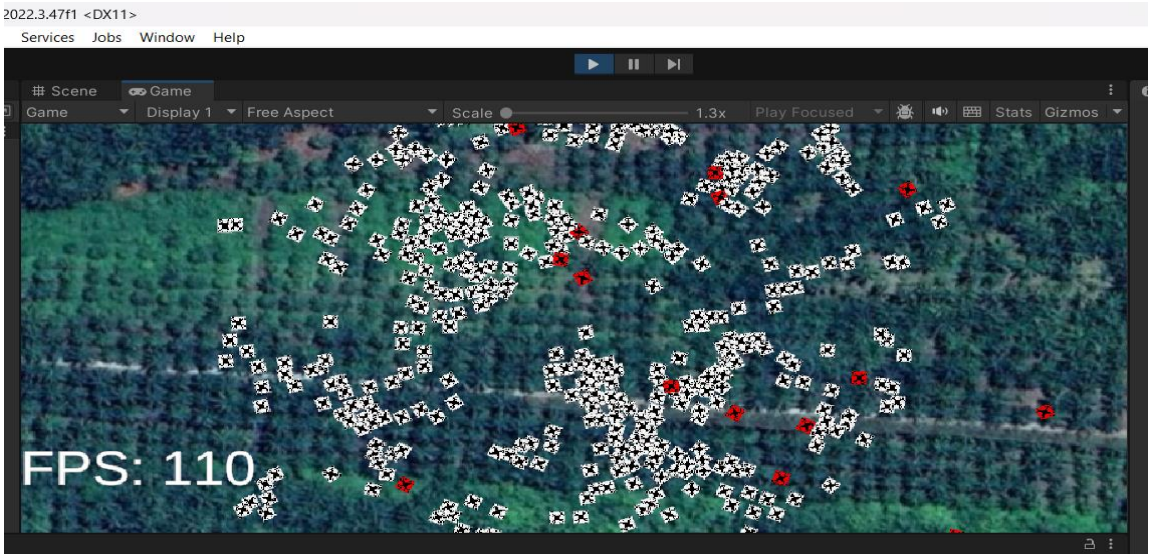
Once the drones arrive at the search zone, this centered flock behavior allows the group to split into smaller units deliberately, optimizing their coverage of different sections. During challenging conditions, like rough terrain or adverse weather, the centered behavior helps maintain both speed and safety by keeping the drones together, minimizing the risk of any drone getting lost or separated from the main flock.

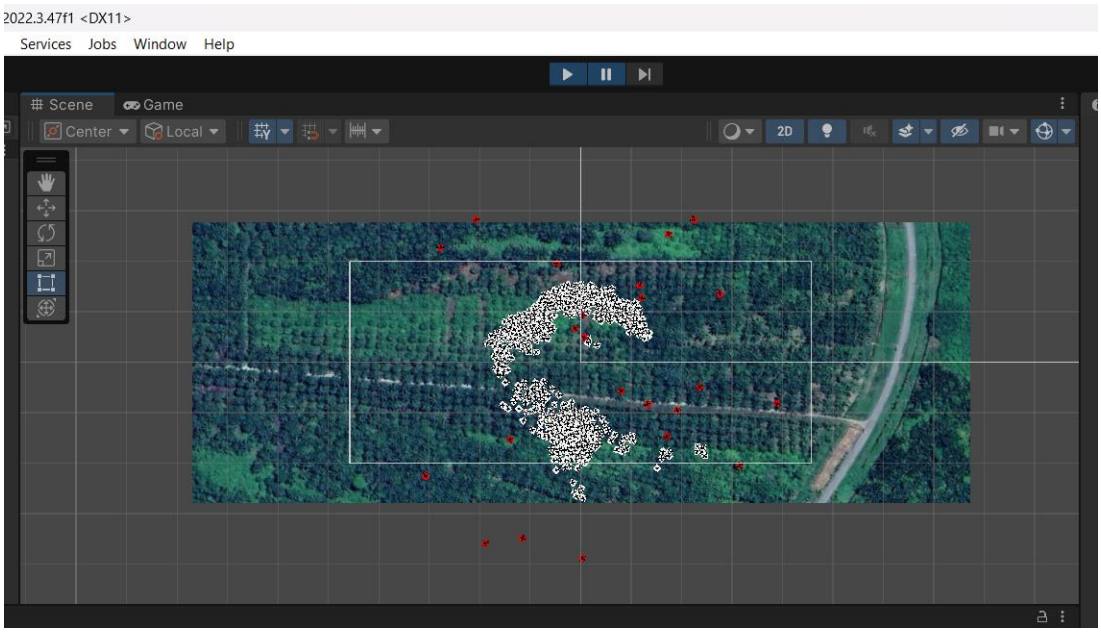
Runtime Report:

The function of **PartitionDronesBasedOnVictims() was run.**



This was the info collected with the average time taken for the function to run as the number of frames increases. The data was taken on 500 drones and 50 victims to rescue.





The drones will pass the area if a person is found one of the drones turns red and stop(hover) where the person is till help arrives.

Example Application for Drone Flocking

Drone-Assisted Search and Rescue: Applications in Disaster Response :

According to Maciel-Pearson, Miranda, and Gonzalez (2020), drones have proven invaluable in search and rescue missions, particularly in environments that are difficult for human responders to navigate. The authors highlight how drones equipped with thermal imaging and GPS tracking can quickly locate survivors in disaster zones, such as collapsed buildings, dense forests, or flood-prone areas, significantly reducing the time it takes to deliver aid. The study also discusses how drone flocks can operate autonomously to cover large areas, coordinating in real time to adapt to changes in the environment or mission parameters.

Autonomous Drone Swarms in Search and Rescue Operations :

As highlighted by Sharma and Patel (2019), autonomous drone swarms have revolutionized search and rescue missions by enabling rapid coverage of large areas. Their research focuses on the coordination between drones in challenging environments, where each drone adapts to dynamic obstacles while maintaining communication with the rest of the flock. This reduces the time required to locate survivors and optimizes the deployment of human resources.

Multi-agent Systems for Search and Rescue with Drones :

According to Lee, Kim, and Choi (2021), multi-agent drone systems are essential for enhancing the effectiveness of search and rescue missions. The study explains how drones equipped with machine learning algorithms can autonomously decide which areas to prioritize based on real-time data, improving mission efficiency in disaster zones.

References

Lee, S., Kim, J., & Choi, D. (2021). Multi-agent systems for search and rescue with drones. *Automation in Construction, 128*, 103728. https://doi.org/10.1016/j.autcon.2021.103728

Maciel-Pearson, A., Miranda, D., & Gonzalez, R. (2020). Drone-assisted search and rescue: Applications in disaster response. *Journal of Field Robotics, 37(*4), 789-803. https://doi.org/10.1002/rob.21983

Sharma, R., & Patel, M. (2019). Autonomous drone swarms in search and rescue operations. *International Journal of Robotics Research, 38(*9), 1123-1137. https://doi.org/10.1177/0278364919872065