Simulation of a Unmanned Aerial Vehicle (UAV) Swarm Control System

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Abstract: A promising direction for the use of UAVs is their association into groups or herds, like the insects observe the principle of swarm organization in the nature. In the case of UAVs, after combining into a swarm, each drone is controlled by its own automation, and the behavior of the swarm can be controlled by a program with elements of artificial intelligence or (several) an operator. In this work, we considered the task of improving the safety of the flight of a group of UAVs in the agro-industrial complex. The simulation of an unmanned aerial vehicle (UAV) swarm control system was created by using the 3D simulator Coppeliasim and the software PyCharm, and it was implemented when monitoring plants in the agro-industrial complex.

1 Introduction

Swarm robotics have many potential applications. These include tasks that require miniaturization, such as distributed sensing tasks in micro machines or the human body. Some of the most promising applications of swarm robotics include search and rescue operations Foroutannia et al. (2021). Swarms of robots of different sizes can be sent to places where rescuers cannot reach safely, to explore the unknown environment using on-board sensors. On the other hand, group robotics could be suitable for applications requiring low-cost construction - such as mining or agricultural operations Kumar et al. (2018). The relevance of this paper is to develop a flight control simulation of a UAV swarm for plant monitoring in agro-industrial complex. In agriculture, the practice of using drones to survey the condition of agricultural plants, monitor the performance of work in the fields, assess the quality of crops,is being actively introduced Pham et al. (2020). UAV(s) are now designed to be used in groups, they can be launched at the target en masse, from several carriers at a time; in flight, they will be able to interact with each other and exchange information - this is known as the UAV swarm.In our case, a swarm of unmanned aerial vehicles will be used for agro-industrial surveillance, with the lead UAV controlled by a pilot (or autopilot) and the slave UAVs working in a co-ordinated manner within a group.

2 Analysis of UAV swarming technology

A UAV swarm, also called a drone fleet, is a coordinated set of drones - air, ground, underground or marine - to perform a common task in different types of applications, civilian or military. work together to achieve the tasks that either cannot be performed by a single drone. Each drone may accomplish a similar role or different roles, such as weapons, or communications relaying Jin et al. (2022). Drone swarming requires a variety of advanced capabilities, such as the ability to maintain a separation to avoid collision and the ability for each tactical drone to predict where its neighbours will be at any one time. These capabilities may be facilitated by real-time sensing as well as artificial intelligence and computer vision algorithms Xiaoning (2020). Swarm communications for UAV may rely on RF (radio frequency), cellular or satellite communications (SATCOM) Tegicho and Bogale (2022).The swarm may use ad-hoc networking technologies, particularly when operating BVLOS (beyond visual line of sight) and over large areas where existing connectivity is not guaranteed. Individual drones may connect to and disconnect from the network all the time, making a decentralized ad-hoc network structure highly Hartley et al. (2022).

2.1 System description

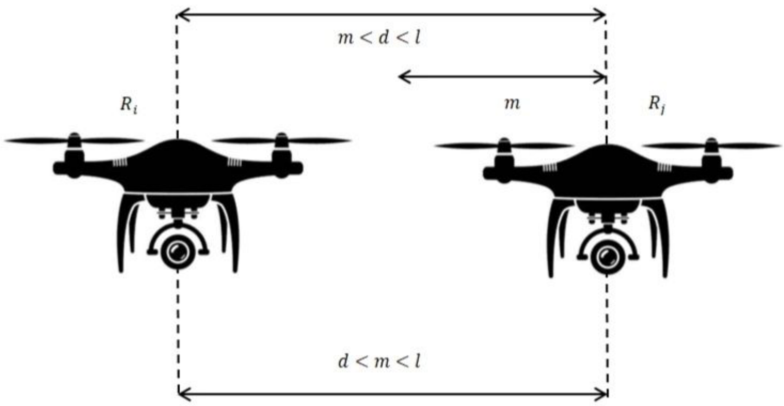

Figure 1: Mathematical model for UAV-to-UAV distance.

Let **m** be the minimum permitted distance between UAVs; **d** - current distance between UAVs R_i and R_j and **L** is the radius of visibility of each UAV R_i and R_j. $\left|\overrightarrow{F_{ij}}(k)\right| \approx \mathrm{d}, \mathbf{m} < \mathbf{d} < \mathbf{L}$, in a straight direction and $\left|\overrightarrow{F_{ij}}(k)\right| \approx \mathrm{d}^{-1}, \mathbf{m} < \mathbf{d} < \mathbf{L}$ in the reverse direction, Where $\left|\overrightarrow{F_{ij}}(k)\right|$ represents the force vector of the distance between UAVs. The UAV(s) in the swarm that has information about the desired direction of motion will be called "leading" UAV(s). And the rest is called "slave" UAV(s). Depending on the nature of information exchange in a UAV swarm, there are two possible scenarios:

- The lead UAV that detects a target tells it neighbour UAV, the coordinates of the target, and so on, and soon all UAVs in the swarm have information about the location of the target and can move in this direction.
- The lead UAV that has detected a target cannot communicate its coordinates to other UAV in the swarm.

2.2 Algorithmic flight program for the UAV swarm

The algorithm shown in Fig. 2 summarises the take-off of the UAV swarm. The first UAV takes off first, followed by the second after 60 seconds if no technical problems are detected. 60 seconds represents the waiting time introduced into the 3D-CoppeliasSim simulation program with python language. **Z** is the height of UAV in reality, and **h** is the height set by the UAV operator.

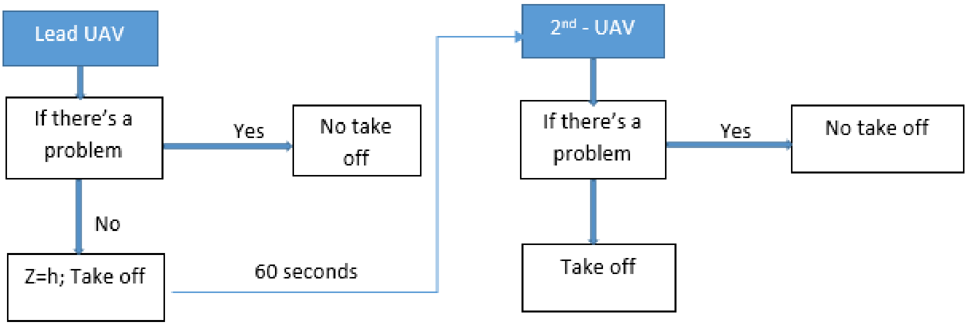

Figure 2: UAV swarm take-off algorithm.

Once the UAV swarm has taken off, its flight will proceed as follows:

- The lead UAV always flies with a time T in front of the second UAV which follows its movement.
- If there is an obstruction, the two UAVs slow down, whether or not they are in the surveillance zone $\{S > L_{min}\}$ (L_{min} is the minimum length covered by the UAVs) and return to the starting point.
- Without obstacles, the two UAVs fly at maximum speed, carrying out their mission.
- During their mission, if there are obstacles, they return to point 2 and if there are no obstacles, they face the condition ($L{=}X$, which is the area to be covered).
- The UAV detects the bad plants and complete their mission.

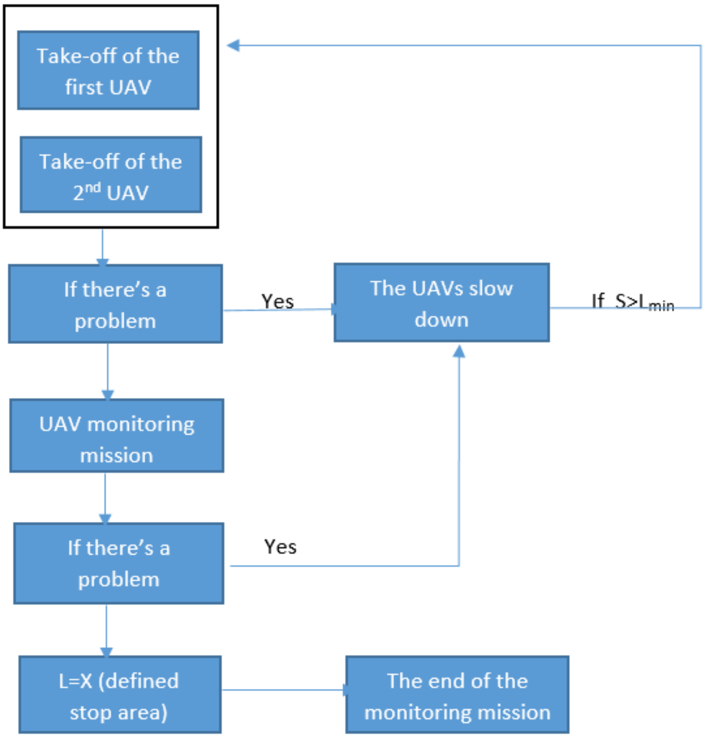

Figure 3: UAV swarm flight algorithm.

After the mission, the UAV swarm turns around to land. The first UAV will then land for 60 seconds, as for take-off, followed by the UAV.

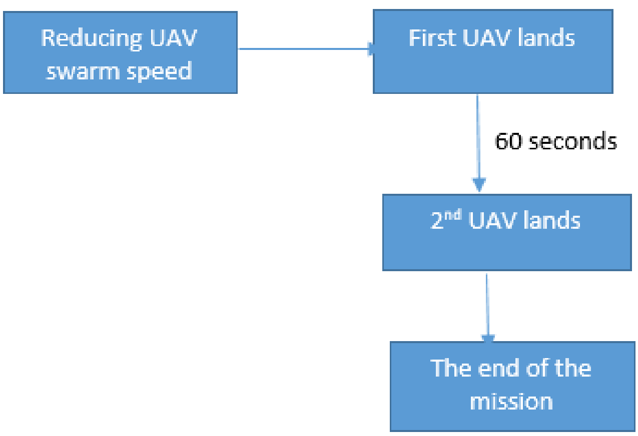

Figure 4: UAV swarm landing algorithm.

3 Results

With the help of the Python programming language application tools and using the CoppeliaSim simulation software environment, the plots of the UAV distribution over the territory were implemented and the distances between the theoretical UAV centers were calculated.

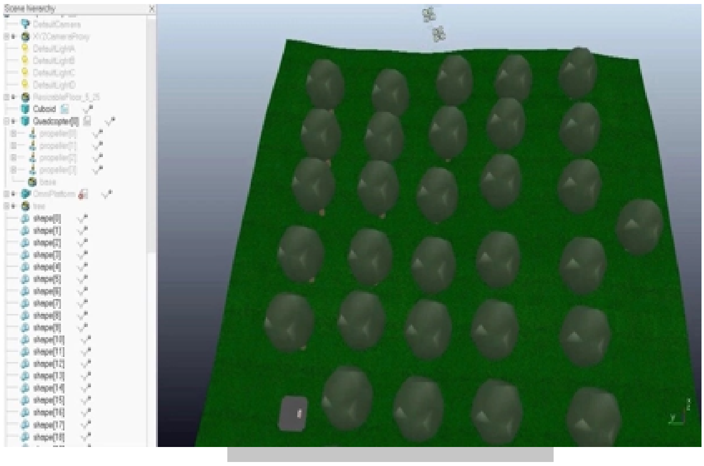

Figure 5: Flight simulation of a swarm of two UAVs in Matlab in 3D Coppeliasim.

the video of this simulation can be seen on this link: *https://drive.google.com/file/d/1Ggsv_jpjV_hM9ej_6L3NXj3b4fNAPMNC/view?usp=drive_link*

4 Conclusions

In this article, the simulation of the drone swarm control system for plant monitoring in the agro-industrial complex has been carried out. For this work, the 3D simulator Coppeliasim and the PyCharm software were used. The following steps were carried out in the process:

- Analysis of drone swarm control technology.
- Development of algorithmic models for UAV swarm takeoff, flight and landing.
- Result of this simulation through a video.

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