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Advancing Wildlife Monitoring in Gregarious Species with Drone Swarms

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Abstract. The widespread adoption of autonomous multi-drone missions in wildlife research remains limited by the absence of readily available automated solutions. In this paper, we present an application of drone swarms to perform monitoring of gregarious species. As part of a PhD project within the interdisciplinary WildDrone consortium, we describe the potential of utilizing drones to gather multi-view data about animals for posture analysis, individual identification, and 3D reconstruction. We introduce our strategy to tackle the deployment of drone swarms for such a task, as well as our methodology to conduct our first real-world tests in January 2025 in Kenya.

Keywords: Drone Swarms · Wildlife Monitoring · WildDrone Project

1 Introduction

This paper presents a PhD project, which is part of the EU-funded MSCA Doctoral Network, WildDrone [1]. WildDrone is a research consortium consisting of 13 different thesis topics, focused on exploring the applications of drone technologies and machine vision in the field of nature conservation. The relevance of this initiative arises from the alarming decline in biodiversity over the past decades. It has become evident that there is an urgent need to develop new conservation methods that are cost-effective, time-efficient, and less labour-intensive [4]. For scientists, data collection is of paramount importance as it enables monitoring the health, behaviour, and populations of animal and plant species. The continuous advancements in the field of aerial robotics have opened up new opportunities for biologists, offering them a versatile experimental platform for conducting aerial surveys. In the scientific literature, drones have already been identified as effective tools in the realm of animal conservation, see [5, 19] for examples.

As part of the WildDrone consortium, the PhD project presented in this paper aims to develop new methods for controlling drone swarms to extend the possibilities of data collection over large areas and among gregarious species, which tend to live in groups or communities. Coordinating multiple drones to collect data simultaneously will allow us to increase the efficiency of data collection and its robustness, as swarm systems are known to be highly error-resilient [20]. To the best of our knowledge, limited research has focused on real-world testing of drone swarms for wildlife conservation. In this project, we aim to move drone swarms out of simulations and laboratories, building on research outcomes from other WildDrone PhDs in biology and computer vision.

2 Problem Statement

Drone swarms can be applied in various contexts within species monitoring. To refine the focus of this PhD project, we have aligned its objectives with those of other members of the consortium who specialize in biology.

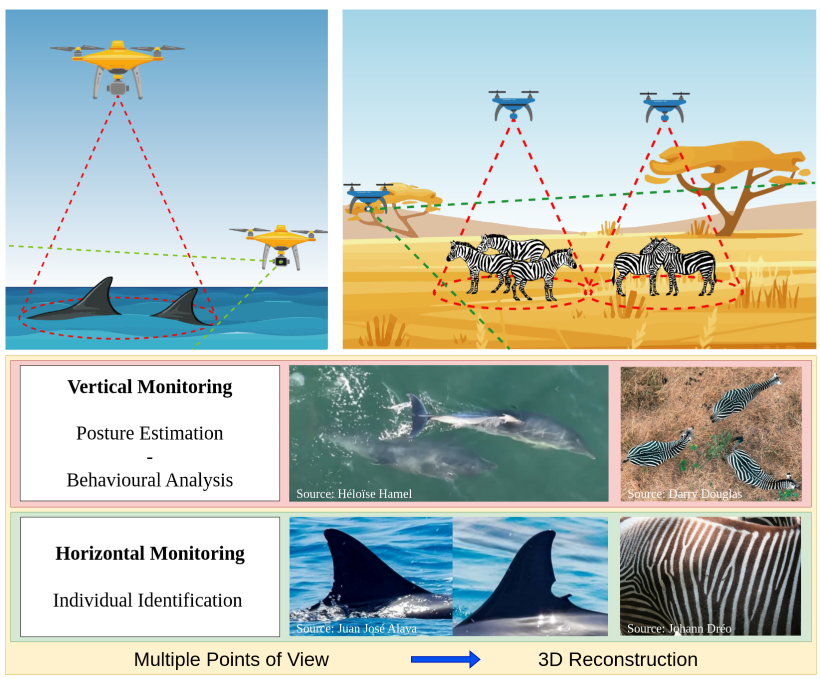

Fig. 1. Illustration of the problem and expected outcomes of multi-view monitoring of gregarious species

The ability to simultaneously collect data from different angles opens up new avenues that can significantly enhance the accuracy and efficiency of wildlife studies. While top-view monitoring can enable the acquisition of information used in wildlife census [3], behavioural studies [10], and posture analysis [11], the addition of lateral views would greatly improve and extend the possibilities. For instance, it would allow for individual identification by recognizing unique and distinctive physical features, such as fin notches or markings for marine mammals [14], and fur coat patterns such as zebra stripes [13], as depicted in Fig. 1. Using multiple viewpoints would also facilitate the creation of detailed 3D reconstructions of individuals and their environments, providing invaluable insights into habitat structure and animal behaviour.

In line with these objectives, this PhD project aims to develop swarm intelligence algorithms for dispatching drones over a group of animals to perform horizontal and vertical monitoring while respecting certain constraints, such as the closest distance to an individual and the spatial resolution of the pictures acquired. Moreover, the drones' positions must be chosen to maximize the number of animals accurately monitored in each configuration. The monitoring quality will be assessed using dedicated metrics defined by the consortium's biologists.

3 Collecting Multi-View Data of Wildlife

Biologists attempting to obtain multi-angle picture or video datasets continue to face limitations. In addition to drone imagery, current methods often involve the simultaneous collection of ground-level data through direct observation [10] or with a hand-held camera [6] to capture additional view angles of the animals. These methods pose significant technical challenges, such as coordinating multiple devices and ensuring data synchronization. To solve the problem depicted in Fig. 1, we have divided it into two sub-problems: vertical monitoring and horizontal monitoring discussed in the sections below.

3.1 Vertical Monitoring

The first sub-problem deals with monitoring animals from a vertical perspective. To date, tracking animal movements and behaviour is primarily accomplished using a single drone, often operated manually. Subsequently, the data collected by the drone is processed using computer vision techniques [12, 17]. The potential of drone swarms for vertical animal observations has been previously explored with gregarious species in livestock monitoring [2]. In their study, Li et al. [15] employed density-based clustering to optimize drone deployment, maximising animal coverage while minimizing the average distance between drones and animals. More broadly, the optimization problem of covering a maximum number of targets with a minimum number of drones has also been addressed using bio-inspired algorithms. For instance, the elephant herding optimization algorithm [21] and artificial bee colony algorithms [22] have been utilized for this purpose.

3.2 Horizontal Monitoring

The use of drones for identification of individual animals in biological studies has been reported in the literature [6, 7]. However, existing protocols for conducting photo identification flight surveys are currently defined qualitatively, with drones being manually flown. These protocols do not establish a standard procedure for positioning the drone relative to the species being studied [6, 7]. Rather, the distance between the animals and the drone is selected to ensure sufficient resolution to identify their individual physical characteristics while ensuring the animals are not disturbed [14]. A step towards automation would be to define, through a model, the likelihood of correct animal identification based on the relative position of the drone and the animal. Such a model could be based on the empirical experience of biologists, but also on specific criteria that have been defined to assess the quality of a photo with respect to identification, such as those described in [8, 14]. This model could thus be used to evaluate the performance of drones conducting the horizontal monitoring, and subsequently to build an objective function. The optimization could be carried out by employing methods used around the *camera placement optimization problem (CPO problem)* defined in [9]. This problem involves optimally placing a certain number of cameras in designated regions to monitor as much of the ground area as possible. A similar approach could be adopted to solve the animal identification problem, this time considering our custom-made objective function. To solve the CPO problem, researchers have explored various strategies, including bio-inspired algorithms like binary Particle Swarm Optimization [16] and a clustering-based multi-resolution optimization method [18] aimed at enhancing the speed of problem resolution.

4 Evaluation Strategy, and Further Work

The WildDrone consortium aims to conduct real-world assessments of drone technologies for wildlife conservation in different natural reserve parks, such as the Wadden Sea in Denmark and the Ol-Pejeta Conservancy in Kenya. The first field trip is planned to be in January 2025 in Kenya. To ensure that we meet the deadline for conducting real-world experiments, we have decided to solve the problem outlined in this paper under stricter assumptions. We define a fixed camera tilt and altitude for each type of drone (vertical or horizontal). Additionally, we assume that the animals are stationary and that their spatial distribution is known. We are currently attempting to solve the optimization problems using a centralized approach and a simulated environment. This environment, depicted in Fig. 2, allows us to utilize 3D models of animals and emulate drone camera views. This initial simplified approach will enable us to quickly transition to the implementation of the hardware solution, ensuring our operational readiness by January 2025.

The experience gained during the first trip and the evaluation of our initial methods will allow us to highlight the limitations of our approach and its potential. The next step will be to introduce a more complex model for the animals, including a spatial distribution based on real data and their potential movement. This will involve making our algorithms responsive to a dynamic environment, thus focusing on a decentralized algorithmic solution to unlock the potential of a fully decentralized system.

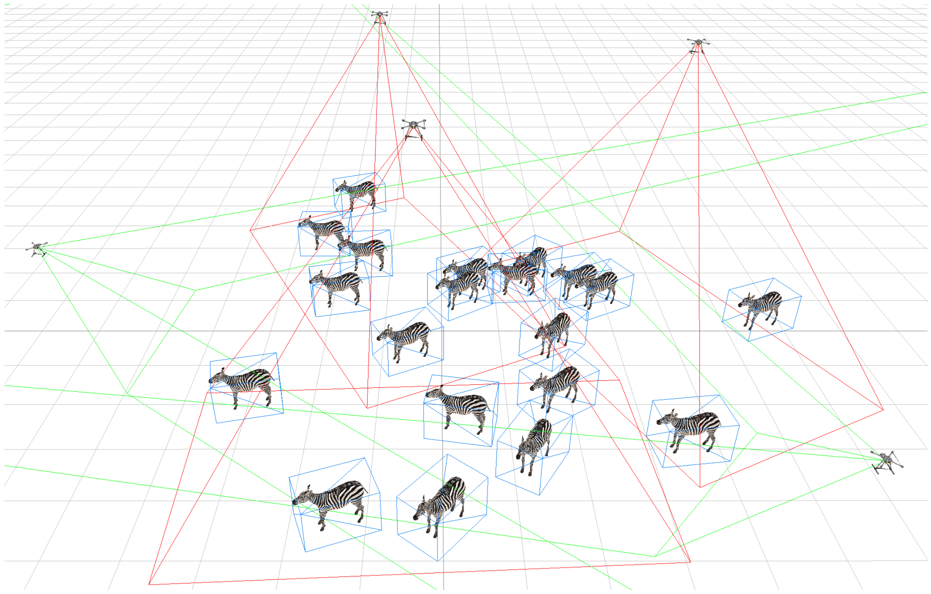

Fig. 2. Drones performing the vertical (red) and horizontal (green) monitoring tasks in the simulator

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