A Short Review On Swarm Of Unmanned Aerial Vehicles

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***Abstract*—Many social insects and animals exhibit collective behavior, which inspires the development of multi-vehicle control systems. The distributed nature of the multi-vehicle control problem improves the collective system's performance in terms of scalability, robustness, and fault tolerance. The cooperative control task's broadcast/decentralized nature introduces a slew of sub-problems frequently associated with network control design of swarm of drones. The purpose of this research is to present a classification of Unmanned Aerial vehicles (UAVs) based on their number of rotors and to examine the fundamental properties of swarming drones. The functionality, challenges, and importance of drones are presented to achieve these objectives.**

***Index Terms*—swarm, UAV classification, joint control**

I. Introduction

A swarm or fleet of UAVs is a group of aerial robots, i.e., drones, that collaborate to achieve a common goal. Each drone in a swarm is propelled by a specific number of rotors and has the ability to hover vertically, take off, and land (VTOL). The drones' flight is controlled either manually, via remote control operations, or autonomously, via processors installed on the drones [1]. Drones are commonly used for military purposes, but their civilian applications have gained popularity in recent years. Indeed, low-cost drones and their swarms offer a promising platform for innovative research projects as well as future commercial applications to assist people in their work and daily lives. Drone swarms can be classified in a variety of ways. Figure 1 depicts fully and partially (semi) autonomous swarms. From another perspective, the classification can be divided into single-layered swarms with each drone acting as its own leader and multilayered swarms with dedicated leader drones at each layer reporting to their leader drones at a higher layer; the highest layer in this hierarchy is a ground-based server station. In each swarm, each drone can have dedicated data collection and processing tasks with enough computing power to execute these tasks in real-time. Its central processing occurs on a more powerful server/base station or even in the cloud.

The purpose of this paper is to (1) investigate the characteristics of drones and swarms of drones and (2) discuss existing technologies of linear and model-based nonlinear controllers. This paper is organized as follows in order to realize these contributions to the field of knowledge. Following this introduction, Section 2 discusses the classification of UAVs. Section 3 investigates the critical properties of autonomous drone swarms. Finally, in Section 4, conclusions are drawn.

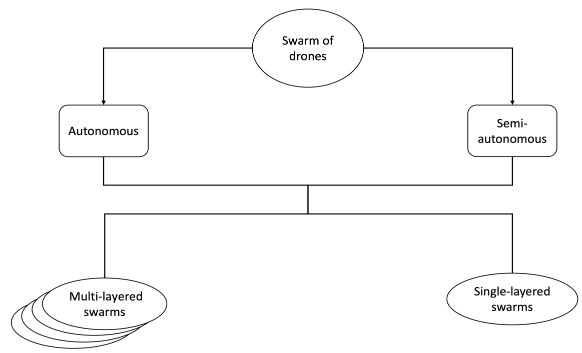

Fig. 1. Classification of swarm of drones

II. UAV classification

The number of propellers/rotors varies among UAVs on the market. Drones can also be classified according to their size, range, and equipment. The size can be nano, mini, regular, or large, and the range can be very close, close, short, mid, or endurance. Drones can be outfitted with cameras, stabilizers, sensors, a Global Positioning System (GPS), and/or First Person View (FPV) goggles.

Drones are classified into four major types [2] which are fixed-wing, fixed-wing hybrid, single rotor, and multirotor. Fixed-wing drones are primarily used for aerial mapping and pipeline/power line inspection. They are costly to operate and necessitate skill training. Though they require more space for launch and recovery, they are capable of covering larger areas. Because these drones are not designed for VTOL/hover, they are unsuitable for general aerial photography. They can, however, stay in the air for up to 16 hours if powered by gas engines.

Fixed-wing hybrid drones, on the other hand, combine manual gliding with automation. They are still in the development phase and are incapable of hovering or flying forward. Amazon commercially employs them for delivery purposes. Single rotor drones, on the other hand, have greater mechanical complexity and operational risks, such as vibration and large rotating blades. As a result, they necessitate operator skill training. They are expensive and have the capability of steering heavier payloads such as LiDAR sensors. They can be powered by a gas engine for even greater endurance.

Among the four types, multirotor UAVs are the least expensive and easiest to build. Drones of this type are commonly used for basic tasks such as photography and video surveillance. Tricopters, quadcopters, hexacopters, and octocopters are examples. Due to their limited speed, flight time, and energy efficiency, these types of drones are not suitable for large-scale aerial mapping and long-distance monitoring. Multirotor drones on the market today can fly for up to 30 minutes with a typical lightweight payload, such as a camera. A quadcopter is the most commonly used UAV type (in terms of the number of propellers), so our discussion in the following sections will be limited to this type.

III. Autonomous drone swarms

A swarm of UAVs equipped with a smart monitoring system can cover a given target area quickly and reliably by utilizing several parallel operating drones. Some important characteristics of autonomous swarms of drones are discussed in this section.

A. Battery Swapping/Recharging

In missions requiring long flight durations, an automatic battery exchanging system for a single drone or a cluster of drones is critical. Lee et al. [3] proposed an autonomous refilling system that used hot battery swapping by providing external power to a drone on the base charging station to prevent data loss during the swapping process. While the drone was at the charging station, this external power source was used to process onboard data and communicate with the base station. This concept was built around a portable rocker arm and a revolving carousel that provided four charging batteries. From landing to takeoff, the battery swap took about 60 seconds. The proposed prototype only served a single quadcopter with a flight time of 15 minutes, and it could charge an exhausted battery in about 45 minutes. In the case of a swarm of drones, the approach proposed in [3] can be improved by allowing the charging station to handle multiple drones (e.g., a full cluster with a leader drone and its worker/slave drones) at the same time. With the advent of UAV swarms and their applications, smart energy management and automated maintenance have become increasingly important. Leonard et al. [4] created an efficient autonomous Ground Recharge Station (GRS) by shortening the charging phase of a single UAV with better and safer electrical contacts. A balancer was used to improve charging efficiency by ensuring proper contact between the circuits on the drone and the charging station. Furthermore, in the case of a swarm of UAVs, the proposed system can use a prioritization algorithm to ensure that a drone with a higher priority is recharged first, followed by a drone with a lower priority.

B. Robustness against Collisions

Mulgaonkar et al. [5] created an 11 cm pico quadcopter with a 25g mass, a 12g maximum payload capable of carrying a small RF camera, and a 2 g carbon fiber cage that protected the device in the event of a collision, allowing it to be recovered. The device was smartly controlled by a custom-designed autopilot board. Delta leader-follower and square formation flight experiments were carried out with promising results to test the copter's capabilities in tight/ dense formations. The drones were also shown to be resistant to collisions at speeds of up to 4 m/s. Shim et al. [6] created a collision avoidance algorithm based on MPC to obtain reliable trajectory prediction for autonomous control of emergency evasive maneuvering. This method was tested in a variety of collision scenarios, including one-on-one and one-to-many patterns. A flight test was conducted using two helicopters to demonstrate the algorithm's efficiency in the case of a face-to-face collision course. Vedder et al. [7] used an inexpensive ultrasound localization method to develop a collision-avoidance system (avoiding collision with obstacles and other copters) for commodity hardware quadcopters in GNSS-denied regions. Three quadcopters and at least two stationary anchors were used in two-dimensional experiments. The testing platform was limited in size due to the maximum allowable distance between the anchors and the copters being 12 m.

C. Surveillance Systems

Mammen et al. [8] used Organic Computing (OC) principles to create a comprehensive framework for designing and controlling swarms of autonomous collaborative robots, with a special emphasis on quadcopters that collaborate with each other to complete spatial tasks. At multiple abstraction levels, the proposed approach facilitated self-optimization of individual drones, optimization of joint efforts between drones, and efficient control of the swarm by the human user. Sadrollah et al. [9] created a distributed relative localization framework for 3D quadcopter swarms, allowing each drone in the swarm to autonomously localize itself in relation to the other drones in the swarm and enabling rapid propagation or dissemination of this localization information throughout the swarm. The framework included an Internet of Things (IoT)-enabled hardware platform mounted on each drone, as well as its operating system and middleware software running on this platform. The proposed work aimed to aid in the development of performant 3D swarming applications and, ultimately, to facilitate the efficient interaction between the human operator at the base station and the swarm.

D. Swarm Design, Management, and Optimization

When considering the mission execution of a swarm of quadcopters, the hovering stability and synchronization of flight mechanisms cannot be overlooked. Niemoczynski et al. [10] used a two-stage controller to generate appropriate control feedback in order to successfully maintain individual drone stability and flight formation synchronization within the fleet, even in the event of a single quadcopter failure.

E. Communication Reliability

Asadpour et al. [11] created and implemented a motion-driven packet forwarding algorithm for multi-hop micro aerial vehicle networks in order to establish connectivity over larger areas. However, the communication link between agents in a quadcopter swarm must be reliable in order for missions to be completed successfully. The Takahashi Self Deployment (TSD) movement algorithm, a network expansion algorithm, was used by Alvissalim et al. [12] to form quadcopter swarm agents for connecting two wireless nodes via an ad hoc network. Olivieri et al. [13] used a bandwidth-efficient multi-robot coordination algorithm based on 3G/4G wireless networks to overcome the challenges of real-time coordination of UAV-based swarms in a wide area setting.

IV. Conclusion and further research

This paper presented a short survey on UAVs (drones) and swarms of UAVs, emphasizing their classification depending on their maneuverability. Consequently, swarm of drones are classified as fully autonomous or semi-autonomous. Further research will be focused on applying artificial intelligence to improve the drones' collision avoidance in an outdoor environment.

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