Research on the design of a subsystem to connect and control multiple unmanned aerial vehicles simultaneously via the MAVLink protocol

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ABSTRACT

This paper introduces an innovative open-source software subsystem that extends QGroundControl to facilitate simultaneous connection and coordinated control of multiple unmanned aerial vehicles (UAVs) using the MAVLink protocol. Key enhancements include a comprehensive Vietnamese-language localization of the user interface, enhancing accessibility for non-English speakers, and a dedicated graphical swarm-management module for streamlined operations. The system ensures full compatibility with PX4 and ArduPilot flight stacks, offering scalable, map-based tools for multi-vehicle mission planning and execution. Furthermore, it supports seamless integration with ArduPilot SITL and Gazebo for robust pre-deployment simulation. Validation in a Software-in-the-Loop environment demonstrates reliable operation with three or more virtual UAVs, including group commands and synchronized mission execution without telemetry conflicts. The resulting cross-platform application (Windows and Linux) is released as open-source software, paving the way for broader adoption in Vietnam's growing UAV ecosystem.

Keywords: UAV; Drone swarm; MAVLink; Ground control station; QGroundControl; ArduPilot.

1. INTRODUCTION

In recent years, unmanned aerial vehicle (UAV) swarms have garnered significant attention due to their transformative potential in diverse applications, from precision agriculture and infrastructure inspection to search-and-rescue and disaster response operations. By enabling coordinated operation of multiple UAVs, these systems provide enhanced coverage, redundancy, and efficiency compared to single-vehicle deployments. Several open-source ground control station (GCS) platforms offer varying levels of multi-vehicle support, including QGroundControl (cross-platform, compatible with PX4 and ArduPilot), Mission Planner (Windows-focused for ArduPilot), MAVProxy (command-line interface), and Paparazzi UAV. Notable advancements include automated mission planning extensions for QGroundControl [1] and experimental leader-follower capabilities in Mission Planner [2]. However, many existing solutions predominantly feature English-language interfaces and often require scripting or command-line interactions for swarm-level functions, limiting accessibility in non-English speaking regions. This study addresses these gaps by extending the QGroundControl framework with full Vietnamese localization and a graphical swarm-management module. Leveraging the native MultiVehicleManager class and MAVLink system IDs, the subsystem simplifies coordinated multi-UAV operations, while also laying the groundwork for future integrations with emerging technologies like AI-driven swarm intelligence.

2. PROBLEM

2.1. Theoretical

A typical UAV system (figure 1) comprises a ground control station (GCS), telemetry link, flight controller, sensors (such as GPS and IMU), and optionally, an onboard companion computer. This

architecture forms the backbone for scalable swarm operations, where efficient communication protocols like MAVLink are crucial for real-time data exchange and command synchronization.

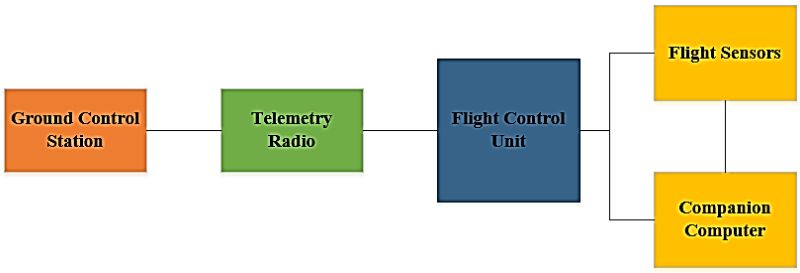

Figure 1. *A typical UAV system.*

2.2. Proposed system architecture

The proposed architecture (figure 2) supports both simulated and real-world swarm deployments under centralized control, while remaining extensible to decentralized algorithms. To enhance robustness, the design incorporates modular components for telemetry routing and conflict resolution, ensuring low-latency performance in multi-UAV scenarios.

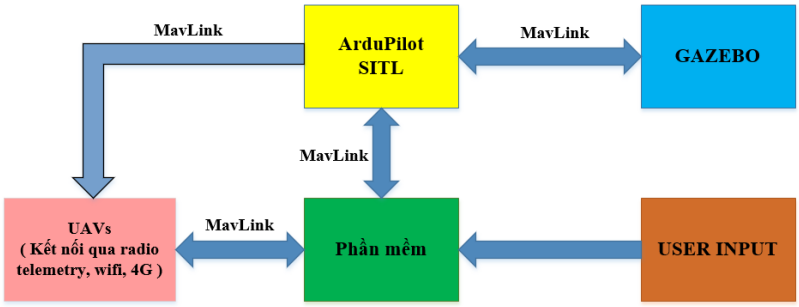

Figure 2. *Proposed drone swarm system architecture.*

3. RESULTS AND DISCUSSION

3.1. Implemented system and key features

The ground control station was developed by extending QGroundControl v4.2+ using Qt 6 and C++/QML. The development process unfolded in four phases: (1) requirements analysis, (2) complete Vietnamese localization of approximately 4,500 UI strings, (3) compatibility verification with PX4 v1.14 and ArduPilot 4.5, and (4) integration of a custom swarm-management plugin.

Key enhancements include: Group command broadcasting (Arm All, Takeoff All, Return All, Land All) via the MultiVehicleManager class. A dedicated Fly View widget enabling simultaneous waypoint and survey-grid assignment across multiple selected vehicles. Advanced error-handling mechanisms to prevent MAVLink message collisions, ensuring system reliability during high-traffic operations.

3.2. Simulation results and comments

The modified ground control station was rigorously evaluated in a Software-in-the-Loop (SITL) environment, utilizing multiple instances of PX4 and ArduPilot SITL integrated with the Gazebo 11 physics simulator (figure 3).

Experiments involved configurations of three to five virtual UAVs, each with a unique MAVLink system ID (1–5). The software maintained stable connections at a telemetry update rate of 10 Hz per vehicle across all tests. Key scenarios included:

Simultaneous arming and synchronized takeoff of the entire swarm (time deviation < 0.8 s between vehicles).

Coordinated waypoint navigation along individual and overlapping trajectories.

Group execution of Return-to-Launch (RTL) and emergency land commands.

No MAVLink message loss or command conflicts were observed in over 50 mission runs, totaling more than 4 hours of simulated flight time. Compared to the stock QGroundControl release, the custom swarm-management module reduced the number of user actions required for multi-vehicle mission setup by approximately 70% (from script-based or sequential individual uploads to single map-based planning). These findings validate the effective utilization of QGroundControl's MultiVehicleManager class and MAVLink system/topic routing for scalable multi-UAV coordination. Moreover, the results highlight the subsystem's potential for real-time applications, where reduced setup time can significantly improve operational efficiency in time-sensitive missions like disaster response.

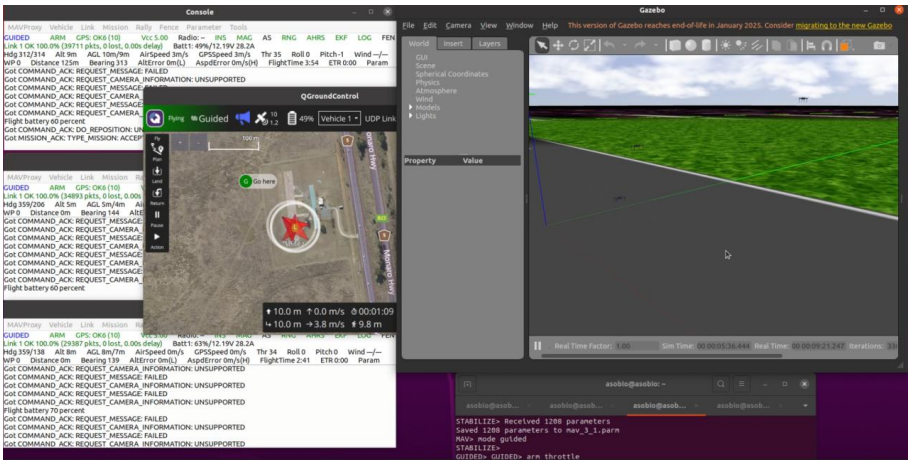

Figure 3. *The Software-In-The-Loop (SITL) simulation environment, showing QGroundControl (left) managing three virtual UAVs running in the Gazebo simulator (top-right) and the underlying flight stack terminal (bottom-right).*

This work introduces the following enhancements to the open-source QGroundControl framework:

Full Vietnamese localization of the user interface.

A dedicated graphical swarm-management module that enables group commands and map-centric multi-vehicle mission design using the existing MultiVehicleManager class and MAVLink system IDs. The resulting software is cross-platform, open-source, and has been validated in simulation with three or more UAVs running either PX4 or ArduPilot firmware.

4. CONCLUSIONS

This research has successfully developed and released an extended version of QGroundControl as open-source software. The subsystem enables simultaneous MAVLink-based control of multiple UAVs equipped with PX4 or ArduPilot firmware, incorporates complete Vietnamese-language localization, and features a graphical swarm-management module for coordinated mission planning and execution. Comprehensive Software-in-the-Loop validation using ArduPilot/PX4 SITL and Gazebo confirms reliable performance with three or more vehicles. Overall, this platform serves as a robust foundation for advancing decentralized swarm coordination, collision avoidance, and real-world deployments, particularly in Vietnam, where it can accelerate the adoption of UAV technology in national defense, agriculture, and emergency services.

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TÓM TẮT

Nghiên cứu thiết kế phân hệ kết nối và điều khiển nhiều phương tiện bay không người lái đồng thời qua giao thức MAVLink

Nghiên cứu thiết kế phân hệ kết nối và điều khiển nhiều phương tiện bay không người lái đồng thời qua giao thức Mavlink. Bài báo trình bày nghiên cứu thiết kế và phát triển phân hệ phần mềm mã nguồn mở cho phép kết nối và điều khiển đồng thời nhiều phương tiện bay không người lái (UAV) thông qua giao thức MAVLink. Mục tiêu chính là xây dựng một trạm điều khiển mặt đất (GCS) mạnh mẽ với giao diện hoàn toàn bằng tiếng Việt, đáp ứng nhu cầu ngày càng cao về ứng dụng bầy đàn UAV tại Việt Nam. Nghiên cứu bao gồm phân tích chuyên sâu giao thức MAVLink, khảo sát các nền tảng GCS hiện có (QGroundControl, Mission Planner), và đánh giá các cơ chế điều khiển bầy đàn. Giải pháp đề xuất mở rộng QGroundControl để phát triển mô-đun quản lý bầy đàn chuyên dụng, tương thích cả với PX4 và ArduPilot. Hệ thống được thiết kế mở rộng, tích hợp công cụ mô phỏng ArduPilot SITL và Gazebo để kiểm thử trước khi triển khai thực tế. Sản phẩm là phần mềm điều khiển đồng thời ít nhất 03 UAV, có giao diện tiếng Việt thân thiện, hỗ trợ thiết kế đường bay tự động đa phương tiện và hoạt động trên cả Windows và Linux. Nghiên cứu đặt nền móng vững chắc cho việc làm chủ công nghệ bầy đàn UAV tại Việt Nam, với tiềm năng ứng dụng rộng rãi trong các lĩnh vực quốc phòng và dân sự.

Từ khoá: UAV; Bầy đàn drone; MAVLink; Trạm điều khiển mặt đất; QGroundControl; ArduPilot.