



# Towards an IoT-Based Unmanned Surface Vehicle Design for Environment Monitoring in Mekong Delta

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**Abstract.** Water quality is a major environmental issue and one of humanity's major issues. For example, although the Mekong Delta has massive water resources from lakes, rivers, and aquifers, the area suffers from problems due to the reduced usable water supplies. Water pollution and salinization have become critical issues in most nations worldwide due to oil spills, plastic waste, sea-level increase, and human activities. Contamination of this nature can harm fish and other aquatic life habitats, agriculture, and, eventually, human health. This paper introduces our IoT-based Unmanned Surface Vehicle design for monitoring the Mekong Delta wetland environment. We explore the use of recent advances in open-source Global Positioning System (GPS)-guided drone technology to design and test a low-cost and transportable small unmanned surface vehicle (sUSV). The vehicle operates using Ardupilot open-source software and can be used by local scientists and marine managers to map and monitor marine environments in shallow areas with commensurate visibility. The USV is equipped with multiple sensors for measuring various water's parameters at different positions. The experimental results show that the prototype version of our USV can work 573 m away from the base station while mean square error (MSE) of telemetry data from sensors compared to certified handheld devices is only 6.2%.

## 1 Introduction

Unmanned Surface Vehicles (USVs) offer several advantages for wetland environmental management. One of the key advantages is the remote Monitoring where USVs can be equipped with various sensors and monitoring devices to collect real-time data about wetland ecosystems. This includes water quality parameters such as temperature, pH levels, dissolved oxygen, and nutrient concentrations. Remote monitoring eliminates the need for manual data collection and allows for continuous, high-resolution monitoring of wetland conditions. USVs

offer the following advantages for environmental management: (i) **Reduced Ecological Impact:** Unlike manned vessels, USVs do not require human operators on board, minimizing the physical disturbance to sensitive wetland habitats. (ii) **Versatility and Adaptability:** USVs can be easily programmed and reconfigured for different tasks and environments. They can navigate narrow channels, traverse complex terrain, and access hard-to-reach areas of wetlands. (iii) **Cost-Effectiveness:** Operating USVs for wetland environmental management can be more cost-effective compared to manned vessels or aerial platforms. They require fewer resources, such as fuel and maintenance, and can be deployed for extended periods without the need for human presence. (iv) **Improved Safety:** Wetlands can present hazardous conditions for human operators due to unpredictable terrain, dense vegetation, or exposure to toxins. By utilizing USVs, the risk to human life and health is significantly reduced as they eliminate the need for personnel to physically enter potentially dangerous areas. (v) **Enhanced Data Accuracy and Integration:** USVs can be equipped with advanced sensors and data acquisition systems that provide accurate and reliable measurements. The collected data can be integrated with Geographic Information Systems (GIS) and other analytical tools, allowing for comprehensive data analysis and visualization. (vi) **Reduced Environmental Footprint:** USVs are typically electrically powered, which reduces their carbon footprint and eliminates direct emissions. They can utilize renewable energy sources, such as solar panels or hydrokinetic energy, for prolonged operation in remote wetland areas.

While Unmanned Surface Vehicles (USVs) offer numerous benefits for environmental management, there are also some technology-related challenges that need to be addressed. Here are a few notable issues: (i) **Navigation and Obstacle Avoidance:** USVs must navigate through complex environments, including waterways with varying water levels, submerged obstacles, and vegetation. (ii) **Autonomous Decision-Making:** USVs often operate autonomously or with limited human intervention. (iii) **Communication and Connectivity:** USVs often rely on communication links, such as satellite or cellular networks, to transmit data, receive commands, or maintain remote control. (iv) **Power Supply and Endurance:** USVs typically rely on onboard batteries or alternative power sources, such as solar or wind energy, to operate. (v) **Sensor Integration and Data Fusion:** USVs often carry multiple sensors and data acquisition systems to monitor environmental parameters. (vi) **Data Processing and Analysis:** USVs generate vast amounts of data during environmental monitoring missions. (vii) **System Reliability and Redundancy:** USVs are expected to operate reliably over extended periods, often in harsh environmental conditions. Addressing these technology issues will contribute to the continued advancement and successful deployment of USVs for environmental management, improving their reliability, performance, and overall contribution to the preservation and sustainable management of natural ecosystems.

The main purposes and contributions of this paper is to present a novel design and implementation of an IoT-based Unmanned Surface Vehicle (IoT-USV) tai-

lored explicitly for environmental monitoring applications. The proposed IoT-USV system aims to provide the following functionalities:

- Autonomous navigation: The USV will be equipped with advanced navigation algorithms and obstacle avoidance mechanisms to operate efficiently in dynamic aquatic environments.
- Multi-sensor data collection: Integrating a variety of sensors, such as water quality analyzers, temperature sensors, GPS, and cameras, to acquire comprehensive and real-time environmental data.
- Data transmission and communication: Establishing a reliable and secure IoT infrastructure to facilitate seamless data transmission from the USV to an onshore base station for immediate analysis and decision-making.
- Energy-efficient operation: Optimizing power consumption to ensure prolonged mission durations and reduced environmental impact.

The rest of the paper is organized as follows. Section 2 summarizes related work in the literature. We introduce our system design in Sect. 3. The first prototype version is presented in Sect. 4. System evaluation is shown in Sect. 5. Finally, we conclude our paper in Sect. 6.

## 2 Related Work

Previous research in the field of environmental monitoring has explored various methods and technologies to collect data from aquatic environments. Manned boats equipped with specialized sensors were commonly used, but these approaches suffer from high operational costs, potential human risks, and limited adaptability to inaccessible or hazardous regions [7,17]. The need for skilled personnel to operate and manage these manned boats adds to the overall expenses and can pose safety concerns, especially in harsh weather conditions or when monitoring hazardous sites [8]. Additionally, the reliance on manned boats restricts the spatial coverage of data collection, leading to limitations in comprehensively assessing the environmental parameters across vast aquatic regions [9].

Remote sensing techniques, such as satellite-based data collection, have proven valuable for large-scale assessments but often lack the necessary resolution for fine-grained monitoring [6,18]. While satellite imagery can provide valuable insights into broad-scale environmental trends, it may not offer the required spatial and temporal resolution to capture fine-grained variations in water quality, especially in coastal and nearshore areas. Furthermore, the presence of cloud cover and atmospheric interference can limit the effectiveness of satellite-based monitoring, making it less reliable for real-time applications [7].

Recent advancements in autonomous vehicles, including USVs, have shown great promise in environmental research [3]. These autonomous vehicles offer several advantages over traditional manned approaches, including reduced operational costs and the elimination of human risks associated with field surveys (Johnson et al., 2021). Furthermore, USVs can access remote and hazardous

areas that may be challenging or unsafe for human-operated vessels, expanding the possibilities for environmental data collection [13, 16].

Several studies have proposed the use of USVs for water quality monitoring, aquatic life surveying, and pollutant tracking [4, 15]. USVs equipped with a variety of sensors, such as turbidity meters, dissolved oxygen sensors, and chlorophyll fluorometers, have been successfully employed to monitor water quality parameters in lakes, rivers, and coastal regions [2]. Additionally, USVs have been deployed to survey and track aquatic organisms, including fish populations and marine mammals, providing valuable ecological insights [10].

However, the incorporation of IoT technology into these platforms to enable real-time data transmission, remote control, and sensor data fusion is an area that demands further exploration [11, 12]. Integrating IoT capabilities into USVs can enhance their environmental monitoring potential by enabling seamless data transmission to onshore base stations. Real-time data communication allows researchers to monitor aquatic environments continuously and respond promptly to any changes or emerging environmental issues. Moreover, IoT-based USVs can be remotely controlled and reprogrammed, enabling dynamic mission adjustments and optimizing data collection efficiency.

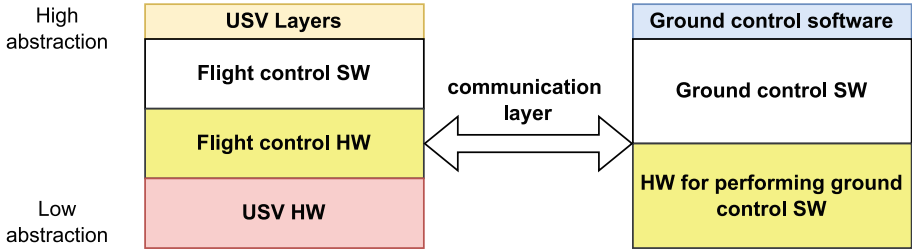
In summary, while previous research has explored various data collection methods in aquatic environments, there is a growing recognition of the potential of autonomous vehicles, particularly USVs, for environmental monitoring tasks. The integration of IoT technology into USVs opens up new possibilities for real-time, data-driven decision-making and resource management strategies [1, 14]. By capitalizing on the benefits of autonomous navigation, multi-sensor data collection, and IoT communication, the proposed IoT-based USV system holds the promise of advancing environmental research and addressing pressing ecological challenges in aquatic ecosystems.

### 3 System Design

The primary objective of the system is to enable vehicle control, offering the option for autonomous operation, pilot input through a ground control station, or interaction with an optional companion computer on board the vehicle. It is even possible to load a fully autonomous mission onto the vehicle for execution. The system consists of two main components: the USV (Unmanned Surface Vehicle) and the Ground Control Station. These components can communicate with each other using the Communication Layer. Figure 1 depicts the overview of the system based on ArduPilot.

Figure 2 depicts the detailed layers of the proposed system. The system consists of five layers as follows.

- Ground Station module: The Ground Station module serves as an essential external software integrated with ArduPilot, designed to operate on a computer stationed on the ground. Its primary function involves establishing seamless communication with an unmanned aerial vehicle (UAV). By facilitating real-time data exchange with the UAV, it becomes a crucial tool for both monitoring and controlling the aircraft's operations.



**Fig. 1.** Overview system for ArduPilot USV

- USV hardware: Another valuable addition to the suite of supported external software, DroneKit is specifically tailored to empower the creation of robust applications for UAVs. This software operates on the UAV’s Companion Computer, unlocking the potential for advanced functionalities and enhanced capabilities within the vehicle’s operational framework.
- MAVLink: An integral external software component deeply integrated into ArduPilot, MAVLink plays a vital role in ensuring effective communication between the system and various ground stations or companion computers. It boasts its own set of protocols that facilitate seamless and efficient data exchange, solidifying the foundation for a reliable and stable communication link.
- Vehicles modules: Central to the versatility and adaptability of ArduPilot, Vehicles Modules represent distinct firmware tailored for each specific vehicle type. This modular approach ensures that the system can be easily customized and optimized to suit the unique characteristics and requirements of diverse UAVs, catering to an extensive range of aerial platforms.
- Shared libraries modules: In an effort to promote code reusability and streamlined development, ArduPilot incorporates Shared Libraries Modules. These reusable code segments encompass core functionalities, sensor integration, and various libraries catering to a wide array of functions, such as control and navigation. By leveraging these shared modules, developers can efficiently build and expand upon the foundation of the system, fostering a collaborative and evolving ecosystem.
- Hardware abstractions layer: An indispensable feature of ArduPilot, the Hardware Abstractions Module ensures portability across an extensive selection of platforms and development boards. By providing a layer of abstraction between the underlying hardware and the software implementation, ArduPilot gains the flexibility to adapt to various setups, allowing developers to experiment and deploy the system on diverse hardware configurations with ease. This capability enhances accessibility and fosters innovation within the ArduPilot community, encouraging the exploration of novel applications and pushing the boundaries of UAV technology.

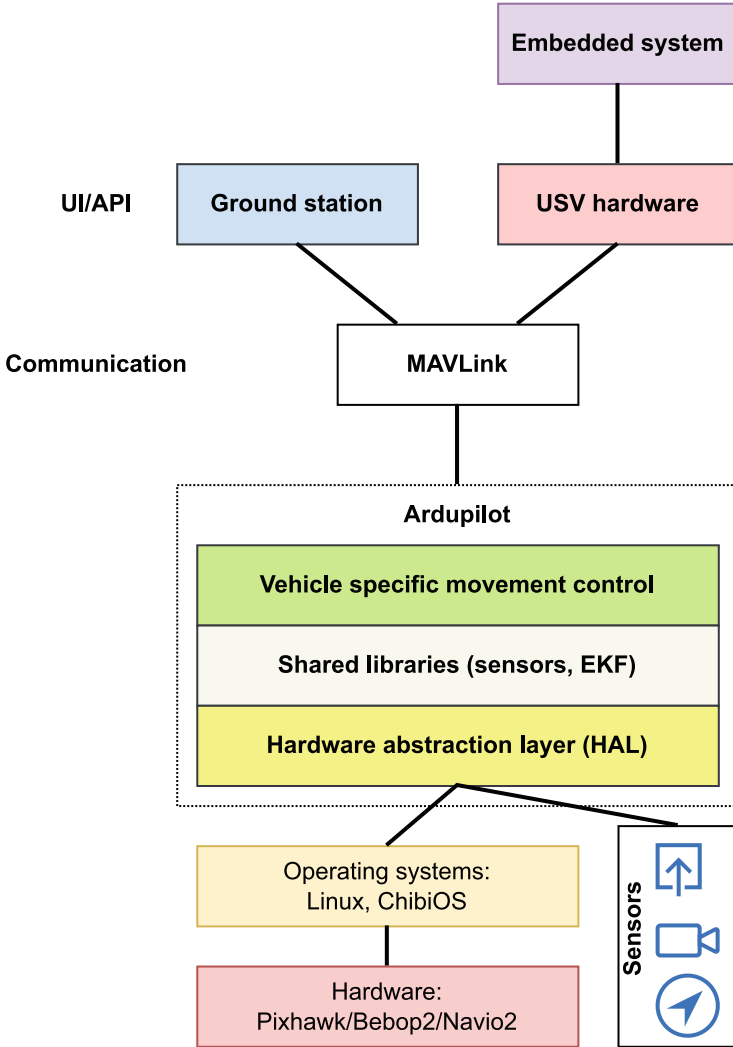


Fig. 2. Detailed layers of the proposed system

## 4 Prototype Implementation

The first prototype version of our USV is built with Raspberry pi 4 model B and the DroneKit-Python - an open source and community-driven project. For sensing data, we use dissolve oxygen, temperature, and PH level sensors.

DroneKit-Python is designed to be compatible with vehicles utilizing the MAVLink protocol for communication. With DroneKit-Python, developers gain the capability to build applications that operate on an onboard companion computer and establish seamless communication with the ArduPilot flight controller

via a low-latency link. By leveraging on board apps, a wealth of opportunities arises to enhance the autopilot system by infusing greater intelligence into the vehicle's behavior. These apps can handle computationally intensive or time-sensitive tasks, such as computer vision, path planning, or 3D modeling, elevating the vehicle's capabilities to new heights.

Furthermore, DroneKit-Python is not limited to onboard applications alone; it also serves ground station applications. In this capacity, it enables communication with vehicles through a higher latency RF-link. This dual capability ensures a comprehensive and versatile toolkit for developers to innovate and create tailored solutions that suit both onboard and ground station requirements, ultimately advancing the realm of UAV technology. Figure 3 presents the GUI of the Dronekit project.



Fig. 3. The GUI of the Dronekit project [5]

## 5 Experimental Results

To evaluate the efficacy of the proposed system and its initial prototype version, we conducted field tests by deploying the Unmanned Surface Vehicle (USV) in the captivating Tram Chim National Park, nestled within the serene Mekong Delta region. Embracing the challenges of the forest environment, we successfully controlled the USV from a remarkable distance of 573 m using RF signal technology.

The evaluation further entailed examining the sensing capabilities of our USV, which produced exemplary results. The measured values demonstrated a

strikingly low mean square error, indicating exceptional accuracy. When compared to handheld devices, our USV's sensor measurements exhibited a mere 6.2% variance, attesting to the robustness and reliability of our technology in diverse environmental conditions.

These encouraging findings validate the potential of our USV system, providing a strong foundation for its continued development and eventual application in a myriad of real-world scenarios, from ecological research in national parks to vital surveillance and monitoring tasks in various industries.

## 6 Conclusion

Water quality stands as a prominent environmental concern and ranks among humanity's most pressing global issues. The Mekong Delta, abundant in water resources from lakes, rivers, and aquifers, faces significant challenges due to dwindling usable water supplies. Water pollution and salinization have emerged as critical problems worldwide, attributable to factors such as oil spills, plastic waste, rising sea levels, and human activities. Such contamination poses a threat to aquatic habitats, fisheries, agriculture, and ultimately, human well-being.

This paper presents an innovative solution through the introduction of our IoT-based Unmanned Surface Vehicle (USV) designed specifically for monitoring the delicate wetland environment of the Mekong Delta. Leveraging recent advancements in open-source Global Positioning System (GPS)-guided drone technology, we have developed a cost-effective and easily transportable small unmanned surface vehicle (sUSV). Powered by Ardupilot open-source software, this agile USV is particularly suited for local scientists and marine managers, enabling them to comprehensively map and monitor marine environments in shallow areas with optimal visibility.

Equipped with an array of sophisticated sensors, the USV facilitates the measurement of various water parameters at multiple locations. Our experimental results showcase the impressive performance of the prototype version of the USV, capable of operating at distances as far as 573 m from the base station. Notably, the telemetry data from the sensors exhibit a mere 6.2% mean square error (MSE) when compared to readings obtained from certified handheld devices, reaffirming the accuracy and reliability of our technology.

By deploying our IoT-based Unmanned Surface Vehicle in the Mekong Delta, we strive to contribute significantly to the ongoing efforts of water quality management, ecological preservation, and sustainable resource utilization. This innovation represents a pivotal step forward in safeguarding vital ecosystems and promoting the well-being of both nature and humanity.

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