Advancements in Cultural Heritage Preservation through IoT and Drone Technologies

Ilenia Ficili*, Luca D'Agati*, Marco Garofalo*, Giuseppe Tricomi*†‡,
Giovanni Merlino*†, Francesco Longo*†, Antonio Puliafito*†
*Università di Messina, Messina,Italy
{ilenia.ficili, luca.dagati, marco.garofalo}@studenti.unime.it;
{gtricomi, gmerlino, flongo, apuliafito}@unime.it
‡ICAR-CNR: Istituto di Calcolo e Reti ad Alte Prestazioni (ICAR) del Consiglio Nazionale delle Ricerche Italiano (CNR)
{giuseppe.tricomi@icar.cnr.it}
†CINI: National Interuniversity Consortium for Informatics, Rome, Italy

***Abstract*—In the rapidly evolving landscape of technology, the preservation of cultural heritage has gained new dimensions with the integration of the Internet of Things (IoT) and drone technologies. This study investigates how these advances are transforming the monitoring, management, and protection of cultural heritage assets. We provide a complete review of current approaches, suggest a new framework for combining IoT and drone systems, and explore practical applications and future possibilities. The possibilities for real-time data collecting, structural health monitoring, and increased public interaction are presented, proving these technologies' revolutionary influence on cultural heritage preservation.**

***Index Terms*—Internet of Things, Cultural Heritage, S4T, AI, ML, Computing Continuum.**

I. Introduction

The preservation of cultural heritage is critical for cultures across the world to keep their identity and past. Historically, cultural site conservation relied mainly on manual inspections and upkeep, which were frequently time-consuming and expensive. However, introducing modern technology such as the Internet of Things (IoT) and drones has marked a new era in cultural asset protection.

The IoT is a network of connected devices that gather and share data, allowing for unprecedented real-time monitoring and administration of cultural heritage assets [4]. Drones, or more in general Unmanned Aerial Vehicles (UAVs), add to the IoT by providing aerial views and access to remote locations. Together, these tools provide a proactive approach to conservation, allowing for early detection of possible problems and prompt response. This study combines information gained from recent advances in IoT and drone technologies to provide an integrated framework for their use in cultural heritage protection. An integrated framework that uses cloud computing and UAV technology to handle important operational difficulties in cultural asset preservation while also being flexible to a wide range of applications and scenarios will also be suggested. This framework attempts to improve obstacle avoidance and establish efficient UAV fleet management by using Stack4Things (S4T) [1]. The suggested technique enables real-time decision-making and autonomous navigation, which is critical for meticulously managing cultural heritage buildings and sites. By merging IoT sensors, UAV capabilities, and cloud computing, the framework enables wide observation, coordinated surveillance, catastrophe preventive actions, and proactive conservation. This integration guarantees that cultural heritage sites are monitored thoroughly and efficiently, maintaining their integrity and historical importance.

II. Proposed Framework

The proposed framework employs cloud computing and UAV technology to address significant operational difficulties in maintaining and enhancing cultural heritage assets. This framework is focused on two main goals: improving obstacle avoidance by exploiting computing continuum techniques and, through the integration with S4T, creating a middleware for efficient UAV fleet management and coordination. This combination enables real-time sophisticated decision-making and autonomous navigation, which is critical for meticulously preserving cultural heritage assets. The S4T framework [1] enables the architecture to combine cloud computing processing power with the agility of UAV technology. This connection enables real-time decision-making and autonomous navigation. Figure 1 depicts the system architecture, showing the linkages between the PX4 firmware [2], S4T cloud agent, and Lightning-Rod daemon, which are crucial to cloud-enhanced UAV operations.

Integrating S4T with PX4 Avoidance it is possible to exploit cloud computing to increase UAV computational capabilities, allowing dynamic obstacle navigation and efficient fleet management. A companion board with the Lightning-Rod daemon mediates the relationship between the PX4 Avoidance system and S4T, allowing communication and operating directives to be exchanged more easily. The PX4 flight control firmware communicates with the avoidance node over the MAVROS bridge, allowing for real-time obstacle detection and navigation modifications. Simultaneously, the Lightning-Rod daemon, which includes a block detection plugin, monitors the UAV's flight path for potential obstacles, providing seamless integration of the UAV's onboard systems and cloud resources. This arrangement is especially useful for monitoring and safeguarding cultural heritage sites since it allows UAVs to navigate complicated areas and collect crucial data while avoiding harm to delicate buildings. S4T's virtual networking

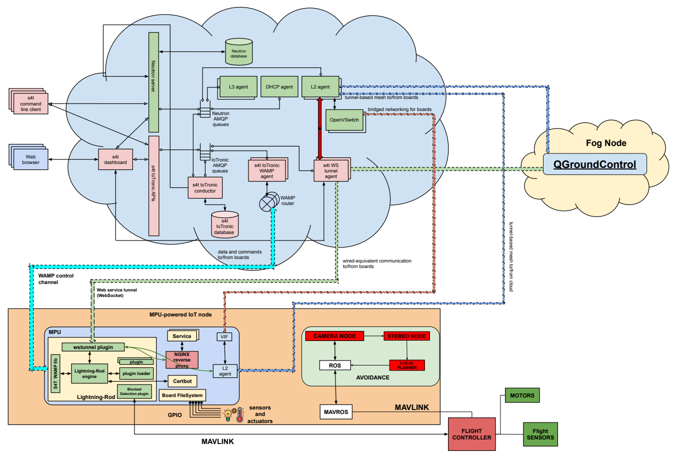

Fig. 1. Architectural integration of PX4-Avoidance with I/Ocloud, showcasing the seamless synergy between onboard UAV systems and cloud computing services.

capability [3] allows UAV fleets to be coordinated inside a single network, increasing resource utilization and ensuring dependable, secure communication. This functionality is critical for missions that need the coordinated operation of several UAVs in a virtual ad hoc network. This capability facilitates comprehensive monitoring and coordinated disaster preventive efforts for cultural heritage locations, allowing UAVs to scan bigger regions more efficiently. This system facilitates proactive conservation initiatives by combining cloud computing with UAV technologies. UAVs can conduct extensive airborne inspections, detect structural faults early on, and provide timely interventions, maintaining cultural heritage structures' integrity and historical value. Additionally, the improved obstacle avoidance and fleet management capabilities allow for more efficient and complete site monitoring, ensuring that conservation measures are thorough and successful.

III. Operative Scenario

This section explores practical and realistic scenarios in which the proposed framework can be implemented to preserve and enhance cultural heritage sites. Combining IoT and cloud-assisted UAV technology for monitoring, maintaining, and conserving cultural assets may yield significant benefits.

A. Monitoring Historical Structures

The framework's principal function is to continuously monitor historical buildings. Real-time data on building structural conditions may be obtained by connecting a network of dispersed IoT sensors and UAVs equipped with high-resolution cameras and distance sensors. UAVs may fly over difficult-to-access regions, such as rooftops and tall facades, to acquire comprehensive photographs and measurements. The data is subsequently sent to the cloud platform for examination. The block-detection mechanism included in the UAVs helps to avoid unexpected impediments during flight missions, ensuring that monitoring activities are safe and efficient. Moreover, the integration of a path-splitting technique could be beneficial for covering large areas in less time, maximizing resource use, and monitoring efficacy. Additionally, visitors may digitally experience cultural landmarks and learn more about their history and significance by utilizing augmented reality (AR) and virtual reality (VR) technology. UAVs, with their high-resolution data-collecting capabilities, play an important part in generating these immersive environments.

B. Disaster Prevention

The ability to coordinate UAV fleets using S4T's virtual networking capabilities is critical for disaster prevention at cultural sites. Natural calamities such as earthquakes, floods, and fires require immediate and coordinated actions to minimize damage. UAVs may be deployed instantly to analyze the disaster's impact, identify risk regions, and monitor rescue efforts. Orchestrating UAV fleets into a cohesive network enables safe and dependable communications, allowing UAVs to work together to cover large regions. This method not only maximizes resource use but also guarantees that all areas of interest are effectively monitored, giving critical real-time data to support operational choices.

C. Enhancing Operational Efficiency

The ability to split mission pathways across many UAVs is fundamental to increase operational efficiency. Moreover, by dividing responsibilities among many UAVs, mission completion durations can be lowered, resulting in faster and more effective coverage of regions of interest. This strategy not only speeds up processes, but it also optimizes resource utilization, lowering downtime and enhancing overall productivity. Implementing this method enables operations to be tailored to a variety of circumstances, increasing the system's flexibility and responsiveness. The ability to separate pathways and allocate particular segments to multiple UAVs makes interventions more quick and precise. This approach is especially useful in complicated and dynamic settings where quick reaction time is critical to operational success. Combining cloud computing and UAV technologies with more advanced methods, such as the path-splitting technique, leads to considerable gains in operational efficiency and cultural asset preservation. This integration marks a significant advancement in the effective management and protection of cultural assets.

References

[1] Francesco Longo, Dario Bruneo, Salvatore Distefano, Giovanni Merlino, Antonio Puliafito, *Stack4Things: An OpenStack-Based Framework for IoT*, in *2015 3rd International Conference on Future Internet of Things and Cloud*, pp. 204-211, 2015. doi: 10.1109/FiCloud.2015.97.

[2] Lorenz Meier, Dominik Honegger, Marc Pollefeys, "PX4: A node-based multithreaded open source robotics framework for deeply embedded platforms," in *Proceedings of the 2015 IEEE International Conference on Robotics and Automation (ICRA)*, 2015, pp. 6235-6240. doi: 10.1109/ICRA.2015.7140074.

[3] Benomar, Z., Longo, F., Merlino, G., & Puliafito, A. (2021). Cloud-based network virtualization in iot with openstack. ACM Transactions on Internet Technology (TOIT), 22(1), 1-26.

[4] M. Maksimović and M. Ćosović, "Preservation of Cultural Heritage Sites using IoT," in *2019 18th International Symposium INFOTEH-JAHORINA (INFOTEH)*, 2019, pp. 1-4, doi: 10.1109/INFOTEH.2019.8717658.