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Cloud Based Analytics Platforms for Scalable Aircraft Forensic Investigation

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Abstract

The increasing digitalization of modern aircraft has resulted in unprecedented growth in aviation data generated from flight data recorders, cockpit voice recorders, aircraft health monitoring systems, onboard sensors, avionics, communication networks, and maintenance management platforms. This rapid expansion of heterogeneous data has transformed aircraft forensic investigation into a data-intensive discipline requiring scalable computational infrastructures and intelligent analytical frameworks capable of processing large volumes of digital evidence efficiently. Cloud-based analytics platforms have emerged as a promising solution by integrating distributed computing, elastic storage, big data processing, artificial intelligence, and machine learning to support comprehensive forensic investigations. This chapter presents a systematic overview of cloud-enabled architectures for scalable aircraft forensic investigation, emphasizing data acquisition, secure integration, cloud-native storage, predictive analytics, automated accident reconstruction, digital twin technologies, and intelligent decision-support systems. Critical aspects of cybersecurity, blockchain-enabled evidence integrity, edge–cloud collaboration, and regulatory compliance are also examined to ensure trustworthy management of aviation forensic evidence. Current challenges involving heterogeneous data integration, computational scalability, privacy protection, interoperability, and explainable artificial intelligence are critically discussed alongside emerging research directions. The proposed analytical perspective highlights the potential of cloud-based forensic ecosystems to enhance investigation accuracy, accelerate evidence processing, strengthen collaborative decision-making, and improve aviation safety through intelligent, scalable, and secure forensic intelligence frameworks suitable for next-generation digital aviation environments.

Keywords: Cloud Computing; Aircraft Forensic Investigation; Big Data Analytics; Artificial Intelligence; Digital Twin; Aviation Cybersecurity.

Introduction

The aviation industry has experienced a profound technological transformation driven by rapid advancements in digital avionics, intelligent sensing technologies, satellite communication systems, and interconnected aircraft platforms [1]. Contemporary aircraft function as highly sophisticated cyber-physical systems that continuously generate enormous volumes of operational data throughout every phase of flight [2]. Information captured by Flight Data Recorders (FDRs), Cockpit Voice Recorders (CVRs), Aircraft Health Monitoring Systems (AHMS), engine control units, navigation systems, structural monitoring sensors, weather observation modules, and communication networks provides comprehensive insight into aircraft performance and operational behavior [3]. Such extensive digital information has significantly expanded the scope of aircraft forensic investigation, enabling investigators to examine accident scenarios using detailed operational evidence rather than relying solely on physical wreckage analysis. Growing data complexity has simultaneously introduced substantial computational challenges associated with collecting, storing, processing, and interpreting heterogeneous aviation datasets [4]. Traditional investigation infrastructures often encounter limitations in scalability, processing efficiency, and collaborative accessibility, creating an urgent demand for intelligent computational platforms capable of supporting modern forensic investigations with greater analytical precision and operational efficiency [5].

Aircraft forensic investigation has evolved from conventional accident analysis into a multidisciplinary scientific discipline that combines aerospace engineering, digital forensics, cloud computing, artificial intelligence, big data analytics, cybersecurity, and data science [6]. Modern investigations require systematic examination of diverse evidence sources, including aircraft telemetry, maintenance documentation, air traffic control communications, radar surveillance records, weather information, satellite observations, and operational logs [7]. Integration of these heterogeneous datasets enables reconstruction of accident timelines, identification of cascading system failures, assessment of environmental influences, and evaluation of operational decision-making processes [8]. Increasing reliance on digital aviation technologies has shifted investigative emphasis toward evidence-driven analytical frameworks capable of discovering complex relationships among interconnected aircraft subsystems [9]. High-frequency sensor measurements and continuous operational monitoring generate multidimensional datasets that exceed the processing capabilities of conventional forensic infrastructures, encouraging adoption of distributed computing environments capable of supporting large-scale analytical workloads while preserving data integrity, traceability, and regulatory compliance throughout the investigation lifecycle [10].