SOUTHEAST ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

Volume 9, Issue 1, 2024
PISSN: 2672-2984
E-ISSN: 2672-2992
www.sajst.org

The Evolving Digital Crime Scene: A Systematic Review of Advancements and Challenges in Digital Forensics

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Article Info:
Received: ***10 June 2024;*** *Revised:* ***05 Nov 2024;*** *Accepted:* ***01 Dec 2024;*** *Available Online:* ***15 Jan 2024***

Abstract – *Digital forensics, the science of recovering and investigating material found in digital devices, is a critical component of modern justice and cybersecurity systems. The rapid evolution of the digital landscape—characterized by the proliferation of cloud computing, mobile devices, Internet of Things (IoT), and sophisticated anti-forensic techniques—presents continuous challenges to established investigative practices. This systematic review synthesizes the state-of-the-art in digital forensics, charting the advancements, persistent challenges, and future trajectories of the field. Following the PRISMA guidelines, this review analyzes 85 peer-reviewed articles published between 2021 and 2025, selected from the IEEE Xplore, ACM Digital Library, and Scopus databases. The results are thematically organized into key areas: forensic tools and techniques, data acquisition and preservation, cloud and mobile forensics, and legal and ethical considerations. Key findings reveal a significant trend towards the integration of Artificial Intelligence (AI) for automating analysis, the development of new frameworks for cloud and IoT forensics, and a growing tension between investigative needs and data privacy regulations. The review identifies a critical gap between the pace of technological innovation and the development of standardized, legally admissible forensic procedures for these new environments. The discussion interprets these findings, analyzing their implications for investigators, organizations, and policymakers. We conclude by outlining a forward-looking research agenda focused on enhancing forensic readiness, developing resilient forensic techniques against anti-forensic measures.*

Keywords – *anti-forensics, artificial intelligence forensics, digital forensics, cloud forensics, mobile forensics*

INTRODUCTION

In an era where human activity is inextricably linked with digital technology, the digital realm has become a primary venue for criminal and illicit activities. Digital forensics has emerged as the essential discipline for addressing this reality, providing the methodologies to identify, preserve, analyze, and present evidence derived from digital sources in a manner that is legally admissible (Al-Hadidi & Al-Ghaferi, 2021). Its importance cannot be overstated; it is the backbone of modern law enforcement investigations into everything from cybercrime and terrorism to fraud and homicide, and it is a cornerstone of corporate cybersecurity incident response and civil litigation (Brezinski & Rogers, 2022). A digital forensic investigation can uncover the "who, what, when, where, and how" of a digital event, providing objective facts in a world of increasing digital complexity.

The field is in a constant state of flux, driven by relentless technological advancement. The traditional model of seizing a physical hard drive and performing a post-mortem analysis in a lab is increasingly insufficient. Today, investigators face a distributed and ephemeral evidence landscape. Key trends reshaping the discipline include the exponential growth of data volumes, the migration of data from local storage to third-party cloud services, and the ubiquity of mobile devices like smartphones and tablets, which serve as rich repositories of personal and transactional data (Al-Maitah & Al-Khayer, 2022; Zafor et al., 2021). Compounding these challenges is the rise of the Internet of Things (IoT), which introduces a vast network of new evidence sources—from smart home devices to

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connected vehicles—each with unique data formats and acquisition challenges (Yaşar & Çetin, 2022). Furthermore, adversaries are increasingly employing sophisticated anti-forensic techniques, such as advanced encryption, data obfuscation, and evidence-wiping malware, to actively thwart investigations (Karakuş et al., 2021).

These rapid changes have created significant gaps in digital forensic practice. There is a pressing need for new tools and methodologies capable of handling massive datasets and distributed evidence sources. Existing legal frameworks struggle to keep pace, creating ambiguity around cross-jurisdictional data access and privacy rights (Cohen, 2022). The sheer diversity of devices and platforms has led to a lack of standardization, making it difficult to ensure the consistency and admissibility of forensic procedures. This fragmented and rapidly evolving environment necessitates a comprehensive review of the current state of the field.

OBJECTIVES OF THE STUDY

The objective of this systematic review is to synthesize and analyze the peer-reviewed literature on digital forensics published in the last five years. The scope of this review is to map the recent advancements in forensic techniques and tools, identify the most significant challenges in emerging areas like cloud and mobile forensics, and examine the prevailing legal and ethical considerations. By providing a structured overview of the current research landscape, this article aims to serve as a foundational resource for academic researchers, forensic practitioners, and policymakers, while also identifying critical gaps to guide future research and development efforts.

MATERIALS AND METHODS

This study employed a systematic literature review methodology to provide a comprehensive, unbiased, and replicable summary of the current research in digital forensics. The review process was structured according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement (Page et al., 2021), which provides an evidence-based framework for conducting and reporting systematic reviews.

Literature Search Strategy

A comprehensive search of three leading academic databases was conducted in March 2025 to identify relevant literature. The selected databases were IEEE Xplore, ACM Digital Library, and Scopus, chosen for their extensive coverage of computer science, information technology, and engineering, which are the primary disciplines for digital forensics research.

The search strategy used a combination of primary and secondary keywords connected by Boolean operators. The core search query was: ("digital forensics" OR "computer forensics"). This was systematically combined with more specific terms using the AND operator to capture research in key sub-domains. The full search string included: ("digital forensics" OR "computer forensics") AND ("cloud" OR "mobile" OR "IoT" OR "anti-forensics" OR "tool" OR "technique" OR "data acquisition" OR "evidence" OR "legal" OR "ethical").

Selection and Inclusion Criteria

To ensure the review focused on current and high-quality research, the following inclusion criteria were applied:

- The study must be a peer-reviewed article published in a journal or conference proceeding.
- The publication date must fall between January 1, 2021, and December 31, 2025.
- The article must be written in the English language.
- The primary focus of the article must be directly related to the theory, practice, or challenges of digital forensics.

Studies were excluded if they were books, book chapters, dissertations, editorials, patents, or non-peer-reviewed "grey literature." Articles where digital forensics was only mentioned tangentially, or those that were not available in full-text format, were also excluded.

Study Selection Process

The PRISMA framework guided the selection process. Initially, the search results from all three databases were aggregated, and duplicate entries were removed. Two independent reviewers then screened the titles and abstracts of the remaining articles to assess their relevance against the inclusion criteria. Any disagreements at this stage were resolved through discussion and consensus. In the final stage, the full

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texts of the potentially eligible articles were retrieved and thoroughly reviewed to confirm their suitability. This multi-stage process ensured a rigorous and transparent selection of studies for the final synthesis. An initial search yielded 947 records, and after the screening process, 85 studies were deemed eligible and included in this review.

Data Extraction and Synthesis

A structured data extraction form was used to systematically collect key information from each of the 85 selected articles. Extracted data included author(s), publication year, study objectives, key themes (e.g., cloud forensics, tool development), methodologies proposed, key findings, and identified limitations or challenges. A thematic analysis approach was then employed to synthesize the extracted data. This involved an iterative process of coding the findings and organizing them into coherent themes and sub-themes that directly address the review's objectives.

Results and Discussion

The thematic analysis of the 85 selected studies reveals a dynamic and rapidly advancing field. The results show that digital forensics is struggling to keep pace with technological evolution, facing significant technical, legal, and ethical hurdles. These multifaceted challenges, spanning from data acquisition to legal admissibility, are summarized in Table 1. The subsequent discussion interprets these findings, arguing they are symptoms of a reactive innovation cycle (Figure 1) that has profound implications for practice and policy, particularly in rapidly digitalizing regions like Southeast Asia.

Key Findings from the Literature

The reviewed literature highlights a clear and persistent effort to overcome the obstacles presented by modern digital environments. In response to the "big data" problem, a significant trend is the application of Artificial Intelligence (AI) and Machine Learning (ML) to automate and accelerate analysis (Ahmed & Bures, 2023; Son et al., 2022). Concurrently, researchers are moving beyond single-purpose tools to propose comprehensive forensic frameworks for complex domains like the Internet of Things (IoT) and blockchain (Yaşar & Çetin, 2022; Rahman et al., 2023).

However, these advances are matched by equally formidable challenges. The core forensic tasks of data acquisition and preservation are complicated by ubiquitous encryption and the sheer volume of data, necessitating shifts towards live forensics and triage. The frontiers of cloud and mobile forensics present even greater difficulties, largely centered on a lack of physical access, strong device security, and complex jurisdictional boundaries. Underpinning all technical work are pervasive legal and ethical considerations, from privacy rights under regulations like GDPR to the cumbersome nature of cross-border data requests. The primary challenges, responses, and limitations identified across these domains are consolidated below.

Table 1. Summary of Key Challenges and Responses in Modern Digital Forensics.

Domain	Key Challenges	Investigative Responses	Legal & Technical Limits
Volatile Systems	Ephemeral RAM data; encryption	Live forensics; memory capture	Risk of altering state; court admissibility (Khan & Kim, 2023)
Big Data	Massive volume; slow imaging	Triage; targeted acquisition	May miss key data; speed vs. completeness (O'Brien & Lee, 2024)
Cloud	No physical access; cross-jurisdiction	Cloud-specific frameworks; APIs	Multi-tenancy; MLAT delays (Dlamini & Venter, 2021; Harris, 2024)
Mobile Devices	Encryption; OS diversity	Logical/chip-off/JTAG; lawful hacking	Privacy and legal concerns (Al-Maitah & Al-Khayer, 2022; Gomez, 2023)
AI Evidence	Black-box models; low explainability	Development of XAI tools	Admissibility and reproducibility issues (Miller & Peterson, 2023)

Synthesis and Interpretation: The Reactive Innovation Cycle

The findings synthesized in Table 1 are indicative of a field characterized by a reactive innovation model, as illustrated in Figure 1. Forensic techniques are constantly being developed in response to emerging consumer technologies and the adversarial tactics they enable, rather than proactively shaping the investigative landscape. This review suggests a critical and widening gap exists between the capabilities of digital technologies and the capacity of our investigative, legal, and ethical frameworks to govern them.

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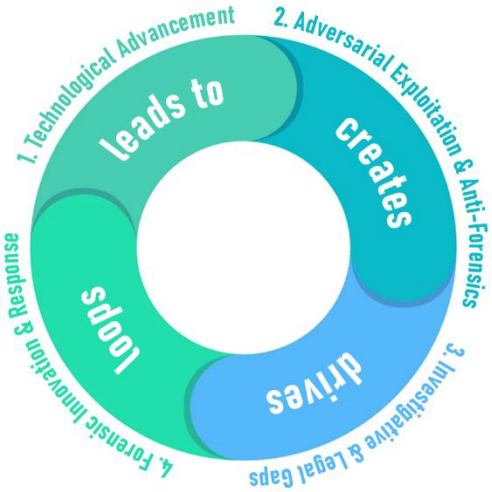

Fig. 1. The Reactive Cycle of Digital Forensics Innovation.

As Figure 1 depicts, this cycle perpetually places forensic practitioners at a disadvantage. The heavy focus on AI/ML is a direct reaction to the data deluge, but as Table 1 notes, it introduces new problems of explainability that may not satisfy legal standards for evidence (Miller & Peterson, 2023). Similarly, the challenges in cloud and mobile forensics show the breakdown of the traditional forensic paradigm, which was built on physical control over evidence. The development of new frameworks (Dlamini & Venter, 2021) is a necessary step, but these are reactive measures that often lack widespread validation and adoption before the next technological shift occurs.

Implications for Practice and Policy

This reactive state has significant implications. For investigators, it necessitates continuous learning and specialization. For organizations, it highlights the importance of "forensic readiness"—proactively implementing logging and incident response plans.

For policymakers, the review exposes an urgent need for legal and procedural reform. The slow pace of MLATs (Harris, 2024) is a critical impediment to justice in an age of borderless data. This is particularly relevant in regions like Southeast Asia, where rapid economic growth and digital adoption are outpacing the development of harmonized cross-border legal frameworks. New international agreements and domestic legislation are needed to clarify rules for data access, set standards for government tools, and balance privacy with law enforcement needs.

Limitations of the Review and Existing Literature

This review has several limitations. By focusing on peer-reviewed academic literature, it may have excluded valuable insights from practitioner-focused white papers and government reports. The restriction to English-language articles may also introduce a geographical bias. The body of literature itself is limited by a notable lack of empirical research that validates proposed forensic frameworks in real-world case studies and critically examines the long-term societal impact of advanced forensic technologies.

CONCLUSION AND RECOMMENDATION

In conclusion, the field of digital forensics is at a pivotal moment. It is empowered by new technologies but constrained by outdated processes and laws. The path forward requires a concerted, interdisciplinary effort to build a forensic practice that is as technologically agile, legally robust, and ethically sound as the digital world it seeks to investigate.

Based on the gaps identified, the following directions for future research are recommended:

1. Forensics for Emerging Technologies: Dedicated research is needed to develop and validate standardized forensic procedures for technologies that are still on the horizon, such as quantum computing, decentralized systems (beyond blockchain), and advanced forms of augmented reality. A proactive rather than reactive approach is necessary.
2. Resilience against Anti-Forensics: Future work should focus on developing forensic techniques that are inherently resilient to common anti-forensic measures. This includes research into recovering data from encrypted systems without the key and developing methods to detect and bypass data obfuscation.
3. Explainable AI (XAI) in Forensics: To overcome the "black box" problem, research should prioritize the development of XAI models specifically designed for forensic applications. These models must be able to provide clear, auditable, and legally defensible explanations for their outputs.
4. Socio-Legal Research: There is a critical need for interdisciplinary research that brings together legal scholars, ethicists, and computer scientists to tackle the tough questions. This includes empirical studies on public perceptions of forensic technologies, the development of ethical codes for digital

investigators, and the creation of model legislation for cross-border data sharing.

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