INTERNATIONAL JOURNAL OF COMPUTER SCIENCE & INFORMATION SYSTEM

Volume10 Issue11, November-2025, pg. 46-51

Published Date: - 22-11-2025

E-ISSN: 2536-7919
P-ISSN: 2536-7900
SJIF 2019: 4.58 2020: 5.046 2021: 5.328

Advancing Automated Security In Devsecops: Integrating AI, Big Data, And Cloud-Native Approaches For Robust CI/CD Pipelines

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Abstract: The convergence of development, security, and operations (DevSecOps) has become essential in modern software engineering, emphasizing the integration of security practices directly into continuous integration and continuous deployment (CI/CD) pipelines. As software systems evolve toward cloud-native architectures and increasingly complex deployment environments, traditional security testing methods have proven insufficient to detect sophisticated vulnerabilities in real-time. This research investigates the implementation of automated security mechanisms within DevSecOps pipelines, focusing on static and dynamic testing, AI-assisted vulnerability detection, big data-driven threat intelligence, and heuristic optimization algorithms. By synthesizing insights from contemporary research, the study identifies critical gaps in current DevSecOps practices, including latency in vulnerability detection, limited integration of predictive analytics, and insufficient alignment of automated security testing with rapid deployment cycles. A methodology emphasizing end-to-end automation, leveraging genetic algorithms for heuristic optimization, and integrating cloud-native security frameworks is proposed. The findings reveal that multi-layered automation enhances security posture, reduces detection latency, and ensures compliance with contemporary security standards. Moreover, the study highlights the strategic role of AI and big data analytics in real-time anomaly detection and predictive threat mitigation. The implications extend to software development organizations, cloud service providers, and security operations centers, providing a roadmap for achieving resilient, scalable, and proactive DevSecOps environments. This research contributes to the ongoing discourse on security automation by offering comprehensive theoretical insights and practical guidance for implementing advanced DevSecOps frameworks in complex, cloud-centric ecosystems.

Keywords: DevSecOps, automated security testing, CI/CD pipeline, AI-driven threat detection, cloud-native security, heuristic optimization, vulnerability management.

INTRODUCTION

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The contemporary landscape of software development is characterized by unprecedented velocity and complexity, driven by the widespread adoption of cloud computing, containerization, and agile methodologies. As organizations increasingly transition to continuous integration and continuous deployment (CI/CD) models, the imperative to embed robust security measures within these processes has never been more pronounced (Hsu, 2019; Smith, Wilson, & Zhang, 2019). DevSecOps, an evolution of DevOps principles, explicitly integrates security practices throughout the software development lifecycle (SDLC), aiming to preempt vulnerabilities and ensure compliance with stringent regulatory standards (Jammeh, 2020; Lee, Kim, & Cho, 2018). However, despite the conceptual clarity and growing adoption of DevSecOps, practical implementation remains fraught with challenges, including tool integration complexities, scalability issues, and latency in detecting emerging threats (Marandi, Bertia, & Silas, 2023; Jones, 2023).

Traditional security testing paradigms, often reliant on manual review and static rule-based detection, are increasingly inadequate in the face of sophisticated cyber threats and dynamic cloud-native environments (Anderson, Brown, & Patel, 2018). Automated security testing—encompassing static application security testing (SAST), dynamic application security testing (DAST), and interactive application security testing (IAST)—has emerged as a critical enabler for embedding security into high-velocity CI/CD workflows (Putra & Kabetta, 2022). Nonetheless, even automated approaches must contend with challenges related to false positives, limited contextual awareness, and incomplete integration with DevOps toolchains (Abiola & Olufemi, 2023; Lorona, 2023).

Recent advances in artificial intelligence (AI) and big data analytics have demonstrated significant potential to augment security capabilities within DevSecOps pipelines. Techniques such as anomaly detection, predictive threat modeling, and heuristic optimization enable proactive identification of vulnerabilities before code reaches production (Zhang, Li, & Wang, 2020; Rao & Kumar, 2019; Malik, 2025). Genetic algorithms, in particular, offer a heuristic approach to optimizing security testing strategies by systematically exploring vast configuration and test-space combinations to identify high-risk code paths and potential vulnerabilities (Thantharate & Anurag, 2023). Yet, the integration of these techniques into real-world DevSecOps workflows remains limited, creating a gap between theoretical potential and practical deployment.

This research addresses the critical question: how can automated, AI-driven security mechanisms be effectively integrated into DevSecOps pipelines to enhance threat detection, reduce vulnerability exposure, and ensure seamless deployment in cloud-native environments? By synthesizing contemporary research and case studies, this study proposes a comprehensive framework that leverages AI, big data analytics, and heuristic optimization to realize resilient, automated, and adaptive DevSecOps processes. This investigation not only delineates methodological approaches but also interrogates the theoretical and operational implications of fully automated security pipelines, offering actionable insights for both academic researchers and industry practitioners.

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METHODOLOGY

The methodology employed in this research involves a systematic synthesis of contemporary literature, case study analysis, and the development of a conceptual framework for automated security in DevSecOps. The study begins by examining established security practices in CI/CD pipelines, emphasizing static and dynamic testing approaches, integration challenges, and existing automation tools (Hsu, 2019; Putra & Kabetta, 2022). The analysis categorizes security mechanisms based on their operational focus: pre-deployment testing, continuous monitoring, and post-deployment incident response.

A central component of the proposed methodology is the integration of AI-driven vulnerability detection. Machine learning and anomaly detection models are evaluated for their ability to process extensive code repositories, runtime telemetry, and cloud-native application logs to identify potential security breaches (Zhang, Li, & Wang, 2020; Rao & Kumar, 2019). Big data frameworks, such as Apache Spark and distributed threat intelligence systems, are incorporated to facilitate real-time analytics and predictive modeling (Patel, Zhang, & Liu, 2017; Wang, Kumar, & Patel, 2019). The heuristic optimization of testing processes is operationalized through genetic algorithms, which iteratively explore test-case configurations and prioritize high-risk code regions, thus enhancing the efficiency and effectiveness of automated security workflows (Thantharate & Anurag, 2023).

To ensure a practical alignment with DevSecOps pipelines, the methodology emphasizes integration with contemporary CI/CD platforms, such as Jenkins, GitLab CI, and GitHub Actions, considering workflow orchestration, pipeline triggers, and security compliance requirements (Marandi, Bertia, & Silas, 2023; Abiola & Olufemi, 2023). The framework also accounts for organizational factors, including developer skill levels, security expertise, and adoption barriers identified in empirical investigations (Jammeh, 2020; Jones, 2023). By combining technological, methodological, and organizational dimensions, the study proposes a holistic approach to automated security in DevSecOps.

RESULTS

Analysis of the literature and case studies reveals several key findings regarding the integration of automated security in DevSecOps pipelines. First, pipelines that incorporate both static and dynamic security testing achieve significantly higher vulnerability detection rates, particularly when AI-based anomaly detection is applied to runtime telemetry and code behavior patterns (Putra & Kabetta, 2022; Rajapaksha et al., 2023). Second, heuristic optimization through genetic algorithms substantially reduces the time required to execute comprehensive security test suites while maintaining high detection fidelity, mitigating the latency challenges traditionally associated with exhaustive testing (Thantharate & Anurag, 2023).

The incorporation of big data-driven threat intelligence further enhances security assurance by enabling predictive analysis of potential attack vectors and emergent vulnerabilities in cloud-native applications (Wang, Kumar, & Patel, 2019; Zhang, Li, & Wang, 2020). Real-time analytics frameworks, leveraging

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distributed computing platforms, provide continuous monitoring and proactive alerting, reducing the window of exposure for newly introduced vulnerabilities (Patel, Zhang, & Liu, 2017; Rao & Kumar, 2019).

Despite these advancements, findings indicate persistent challenges in tool interoperability, false positive management, and the need for skilled personnel to interpret AI-generated insights (Jones, 2023; Lorona, 2023). Additionally, security automation is most effective when coupled with organizational policies and governance structures that enforce compliance and accountability throughout the DevSecOps pipeline (Bitra & Achanta, 2021).

DISCUSSION

The results underscore the transformative potential of integrating AI, big data, and heuristic optimization into DevSecOps pipelines. By embedding advanced security mechanisms directly into CI/CD workflows, organizations can achieve proactive vulnerability management, significantly reducing the likelihood of security breaches reaching production environments (Hsu, 2019; Smith, Wilson, & Zhang, 2019).

However, several limitations emerge from the analysis. First, the reliance on AI and heuristic algorithms introduces risks associated with model bias, overfitting, and interpretability. Security practitioners must balance the automation benefits with the need for transparent and explainable decision-making processes, particularly when addressing regulatory compliance or incident response (Rajapaksha et al., 2023). Second, the scalability of automated security frameworks in large, heterogeneous cloud-native environments remains a concern, as performance bottlenecks may arise when processing high-volume telemetry and code repositories (Anderson, Brown, & Patel, 2018; Lee, Kim, & Cho, 2018).

Future research directions include the development of standardized interfaces for integrating AI-driven security tools with diverse CI/CD platforms, exploration of reinforcement learning for adaptive security testing, and longitudinal studies to assess the operational impact of automated DevSecOps practices across multiple organizational contexts. The theoretical implications suggest that automation, when strategically combined with predictive analytics and heuristic optimization, can redefine security assurance paradigms, shifting the focus from reactive detection to anticipatory threat mitigation (Malik, 2025; Thantharate & Anurag, 2023).

CONCLUSION

This research provides a comprehensive analysis of automated security integration within DevSecOps pipelines, highlighting the synergistic roles of AI, big data, and heuristic optimization in enhancing vulnerability detection, compliance, and operational resilience. The study identifies key gaps in current practice, proposes a holistic methodology for secure CI/CD deployment, and elucidates the theoretical and practical implications of advanced automation in security operations. By bridging the divide between conceptual frameworks and practical deployment, this research offers a strategic roadmap for

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organizations aiming to implement robust, adaptive, and proactive DevSecOps processes, ensuring that security is an intrinsic, rather than additive, aspect of software development.

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