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The Role of Testing in Software Security Assurance

Anatolii Tymoshchuk [1]*

[1] Expert in automated testing of applications and websites. Architect of a framework for web application test automation Glendale, California, United States

Abstract
The article examines the role of testing in ensuring software security, a topic of growing relevance due to the increasing complexity of IT systems and the rise in cyber threats. Software has become a critical component of enterprise infrastructure, government institutions, and everyday human life. Therefore, ensuring software security through effective testing has become one of the key priorities in the modern IT industry. This study explores contemporary security testing methods, encompassing both traditional approaches such as functional testing, penetration testing, static and dynamic code analysis, as well as modern automation techniques leveraging machine learning algorithms. A comprehensive analysis of publicly available scientific publications was conducted, focusing on the integration of security testing into the software development lifecycle (SDLC), with an emphasis on CI/CD practices, distributed testing, and continuous monitoring. The practical significance of this research lies in the applicability of the examined approaches to enhancing the security of information systems in a rapidly evolving IT landscape. The article will be of interest to cybersecurity specialists, lead developers, testing methodology researchers, and academics seeking to integrate advanced testing approaches into strategic cybersecurity measures for software systems.

Keywords: security testing; test automation; machine learning; SDLC; testing integration; cybersecurity; software.

1. Introduction

Traditional testing methods often fail to detect vulnerabilities in a timely manner due to technological advancements and the increasing complexity of software architectures. A comprehensive approach that combines classical quality control methods with modern automation tools and machine learning techniques is necessary. This approach not only enables the timely detection of defects but also allows for the prediction of potential security threats, which is critical for preventing incidents.

Modern research in software testing for security assurance demonstrates a variety of approaches, influenced by both technical and methodological factors. Ustimenko L. R., Bileka T. O., and Safonov I. A. [1] illustrate that integrating machine learning algorithms into testing processes reduces the share of routine tasks and enhances the adaptability of test scenarios. Koch M. [3] provides fundamental principles and practical recommendations for using machine learning in software engineering, serving as a theoretical foundation for further studies in test automation. Menzies T. and Shen Y. [4] contribute by applying machine learning to estimate software development effort, which indirectly affects testing quality and, consequently, the security of the final product.

Redkin P. A. and Alyoshkin A. S. [2] propose a software suite for distributed testing of web applications, demonstrating increased defect detection efficiency through parallel test execution. Armando Y. and Rosalina R. [5] describe the use of the OWASP Top 10 framework in software security testing. A systematic review of testing techniques conducted by Hanna S., Ahmad A. A. S. [6], and Ali H. M., Hamza M. Y., Rashid T. A. [7] explores a broad range of applied methods, although a unified evaluation system for their effectiveness remains lacking. Special attention is given to emerging challenges posed by Web 3.0 technologies, as illustrated in the review by Li H. et al. [8], where the authors analyze approaches for detecting vulnerabilities in smart contracts, emphasizing the need for specialized tools to test next-generation applications. Sources [9-12], published on platforms such as jit, builtin, kaspersky, and anti-malware, highlight corporate experiences in leveraging modern technologies for security testing.

The objective of this article is to examine the role of testing in software security assurance.

The scientific novelty of the study lies in the analysis of publications, which has identified the advantages and limitations of various testing methods, offering new perspectives for developing effective security assurance approaches. The proposed hypothesis suggests that integrating traditional testing methods with modern automation tools and machine learning algorithms enhances the efficiency of vulnerability detection and cyber threat prevention. The research methodology is based on a comprehensive analysis of contemporary scientific literature and an empirical approach to the development and validation of the proposed testing model.

Modern methods of software security testing

Ensuring software security is a key priority in the modern IT industry, as vulnerabilities often lead to serious cybersecurity incidents. Contemporary security testing methods encompass both traditional approaches and modern techniques that enable timely identification and mitigation of potential threats. Classical security testing methods rely on functional testing, penetration testing, and vulnerability scanning. Functional testing verifies whether a system meets specification requirements, serving as a fundamental step in security assurance. Figure 1 below presents the procedures used in software security analysis.

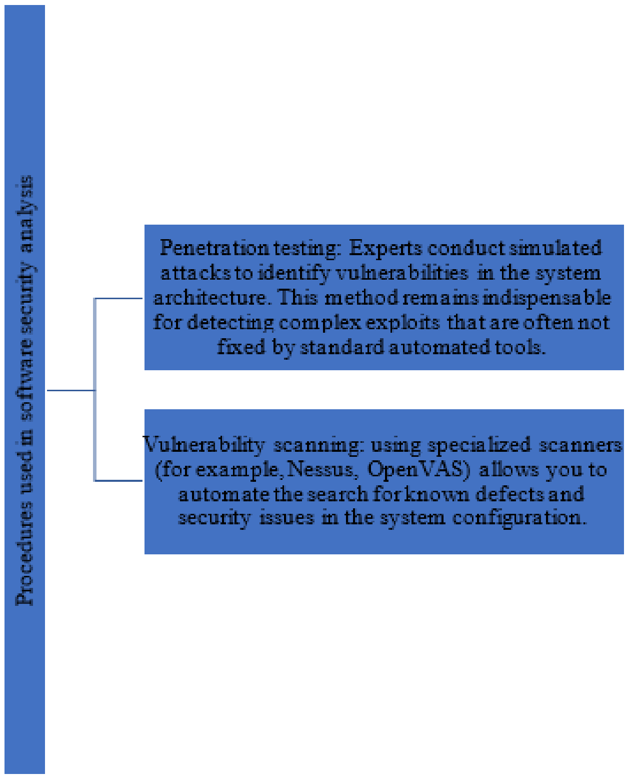
Procedures used in software security analysis
Penetration testing: Experts conduct simulated attacks to identify vulnerabilities in the system architecture. This method remains indispensable for detecting complex exploits that are often not fixed by standard automated tools.
Vulnerability scanning: using specialized scanners (for example, Nessus, OpenVAS) allows you to automate the search for known defects and security issues in the system configuration.

Fig.1. Procedures used in the analysis of software security [1].

These methods form the foundation for early vulnerability detection; however, they often require significant time and human resources, limiting their applicability in rapidly evolving development environments. To analyze software security, static and dynamic code analysis methods are widely used:

- Static code analysis involves automated examination of source code without execution. Tools such as SonarQube and Fortify Static Code Analyzer help identify potential defects and vulnerabilities in the early stages of development. The primary advantage of this method is the ability to detect issues before system deployment [3].
- Dynamic code analysis is conducted in conditions that closely resemble real-world operations, allowing observation of an application ' s behavior under external influences. This approach is particularly

useful for assessing a system's resilience to real-time attacks [4].

- Both methods complement each other: static analysis detects potential issues before execution, while dynamic analysis evaluates vulnerabilities in a runtime environment, which is particularly important for security testing.
- Automated testing enables the following:
- Accelerated verification processes: Specialized tools such as OWASP ZAP and Burp Suite enable rapid scanning of applications for known vulnerabilities.
- Continuous monitoring: Automated systems integrate into CI/CD pipelines, allowing security testing at every stage of development and release updates [1, 5].
- Machine learning applications: Modern solutions leverage machine learning techniques to analyze large volumes of test data, helping predict potential system instability and detect anomalies that traditional methods may overlook [2, 4].

At the same time, manual testing remains essential for interpreting complex attack scenarios that require expert analysis and unconventional approaches. For a clearer comparison of the main security testing methods, Table 1 below presents an overview.

Table 1. Comparison of the main software security testing methods [1, 4, 6, 7].

Testing Method	Advantages	Disadvantages
Manual Testing (Penetration Testing)	High accuracy in identifying complex exploits In-depth expert analysis of specific vulnerabilities	Time and resource-intensive Dependence on specialist expertise
Automated Testing	Rapid detection of known vulnerabilities Continuous monitoring through CI/CD integration	Limited ability to detect non-standard attacks Dependence on updating databases of known vulnerabilities
Static Code Analysis	Early detection of potential defects Automation and seamless integration into development processes	Potential for false positives Does not account for dynamic system behavior
Dynamic Code Analysis	Evaluation of system behavior under real-world conditions Identification of vulnerabilities that appear only during execution	Requires a test infrastructure that closely replicates the production environment High computational load

Modern software security testing methods represent a comprehensive approach, where traditional techniques (functional testing, penetration testing, static and dynamic analysis) are effectively complemented by automated systems leveraging machine learning. This integrated strategy enhances the accuracy of vulnerability detection and ensures comprehensive protection of software systems in an environment of constantly evolving threats.

2. Automation of security testing and the application of modern technologies

Modern automation technologies, particularly the integration of specialized tools and machine learning algorithms, enhance defect detection efficiency, reduce time costs, and ensure continuous monitoring of software security. This section explores the main directions in security testing automation and provides examples of modern technologies applied in this field.

Contemporary automated security testing systems rely on specialized scanners and frameworks that enable regular checks for known vulnerabilities in software products. Tools such as OWASP ZAP and Burp Suite are widely used for dynamic testing of web applications, simulating attacks and identifying potential system configuration flaws. Their integration into continuous integration and delivery (CI/CD) pipelines facilitates timely updates of vulnerability databases and automated testing of each software release [1]. This approach reduces the time required for manual testing and enables systematic security monitoring even in high-speed development environments.

One promising area is the application of machine learning in security testing processes. Classification, clustering, and anomaly detection algorithms analyze vast volumes of logs, monitoring data, and test results to identify patterns associated with potential vulnerabilities [3]. Examples of companies implementing these approaches include:

- Demisto, a company promoting the SOAR (Security Orchestration, Automation, and Response) approach in cybersecurity, applies machine learning algorithms in its visual monitoring panel to prioritize potential threat alerts [10].
- Kaspersky Lab integrates machine learning models into its antivirus products to reduce false positives, enhance result interpretability, and improve resistance to attacker actions. It employs decision trees, locally stable convolutions, behavioral models, and clustering algorithms [11].
- Microsoft has developed its Windows Advanced Threat Protection system for proactive protection, threat detection, automatic investigation, and incident response. Integrated into all Windows 10-based devices, this product is widely used alongside the company's cloud services [10]. The Windows Defender ML system performs daily behavioral analysis of extensive datasets to prevent potential attacks. For instance, when a malicious cryptominer is installed in a user's browser, the system identifies and blocks the threat within milliseconds. Similar threats at the enterprise level are neutralized within seconds due to the efficient application of machine learning methods [12].

The use of neural networks for predicting system instability and automated anomaly detection has already proven effective in several studies [4, 6]. This approach accelerates the testing process while improving the accuracy of identifying previously unknown threats, adapting to changing software operating conditions.

Integrating automated security testing tools into the software development lifecycle requires the formation of a specialized system architecture that includes the following components:

- Data collection and storage: Establishing centralized repositories for logs, metrics, and test results to ensure access to historical data for model training.
- Data preprocessing: Cleaning, normalizing, and aggregating data for further analysis using machine learning algorithms.
- Model training and updating: Developing adaptive models capable of detecting anomalies and predicting potential threats based on historical data, followed by integration into the testing process.
- CI/CD integration: Automated execution of test scenarios with subsequent result analysis and report generation for timely decision-making. For instance, Jit employs additional control points and filters in CI/CD processes to ensure that every code change undergoes vulnerability checks—regardless of its size. Each code

modification triggers a scan, and if an issue is detected, developers receive immediate notifications, allowing them to apply fixes without disrupting project timelines [9].

This architecture facilitates continuous improvement in testing quality through feedback loops and model updates, which is particularly critical in the rapidly evolving IT landscape [1, 3, 4]. For a comparative analysis of the discussed technologies, Table 2 summarizes key aspects of automated security testing.

Table 2. Comparison of modern security testing automation technologies [1, 3, 4].

Technology / Tool	Advantages	Limitations
Automated Scanners (OWASP ZAP, Burp Suite)	Rapid detection of known vulnerabilities CI/CD integration capability Regular updates of vulnerability databases	Limited ability to detect complex exploits Dependence on the accuracy of vulnerability databases
Machine Learning Methods	Identification of anomalies and non-standard patterns Prediction of potential threats Adaptability to changing conditions	Requires large volumes of high-quality data Complexity of result interpretation Need for continuous model updates
CI/CD Integration (Automated Test Scenarios)	Continuous security monitoring Fast response to changes Reduction of manual workload	Initial infrastructure setup costs Requires expert maintenance

Thus, the application of modern automation technologies, particularly the integration of specialized vulnerability scanners and machine learning methods, expands the capabilities of security testing. A comprehensive approach combining dynamic monitoring, big data processing, and continuous integration enhances the efficiency of threat detection and ensures robust system protection in a rapidly evolving IT environment.

3. Integration of security testing into the software development lifecycle

Modern software development approaches based on Agile, DevOps, and continuous integration/continuous delivery (CI/CD) principles require the implementation of comprehensive security measures at all stages of the software development lifecycle (SDLC). Given the constant emergence of new threats and rapid functional updates, traditional security testing methods no longer meet the demands of an ever-changing development environment. In this context, integrating security testing into SDLC becomes essential for timely vulnerability detection and rapid response to emerging cyber risks [1].

In the initial stages of development (requirement analysis and design), particular attention is given to risk assessment and threat modeling. Techniques such as architectural vulnerability analysis and preliminary security requirement evaluations help identify potential attack vectors before system implementation. During the development and coding phase, procedures such as static code analysis, security code reviews, and unit testing are implemented to detect defects that could lead to security breaches [3]. During integration and system testing, dynamic analysis, penetration testing, and automated vulnerability scanning (using tools such as OWASP ZAP or Burp Suite) are employed to assess system performance under conditions close to real-world operation [6]. Finally, in the deployment and operational phases, continuous monitoring with SIEM systems, intrusion detection systems (IDS), and log analysis ensures rapid incident response and maintains an up-to-date security posture [1].

In modern CI/CD environments, automated security testing plays a key role. Every code change automatically triggers test scenarios that include static and dynamic analysis as well as penetration testing. Test results are fed into a feedback system, enabling prompt adjustments to the development process and rapid mitigation of identified vulnerabilities. This approach reduces the accumulation of defects and enhances the reliability of the final product. Moreover, integrating automated security testing tools significantly reduces the time spent on routine checks and ensures more frequent and detailed security assessments [4, 7].

Effective integration of security testing requires seamless information exchange between development, testing, and security teams. Test results are used to refine system architecture, improve code quality, and strengthen resilience against external attacks. In many modern projects, distributed testing is employed, where test scenarios are executed in environments that closely resemble real-world conditions (using cloud solutions and containerization), increasing data representativeness and minimizing the impact of the test environment on verification results [1, 6].

For a clearer representation of the main stages of security testing integration into the software development lifecycle, Table 3 presents a comparison of SDLC stages, applicable methods, tools used, as well as key advantages and limitations of each approach.

Table 3. Main stages of integration of security testing in SDLC [1, 4, 7].

SDLC Stage	**Security Testing Methods**	**Tools/Approaches**	**Advantages**	**Limitations**
Requirement Analysis and Design	Threat modeling, security requirement assessment, risk analysis	Microsoft Threat Modeling Tool, OWASP SAMM	Early identification of potential threats; architecture refinement	Dependence on analyst expertise
Development and Coding	Static code analysis, security code reviews, unit testing	SonarQube, Fortify SCA, integration with GitLab CI/CD	Detection of vulnerabilities before system build; reduction of defects at the coding stage	Potential false positives; requires expert interpretation
Integration and System Testing	Dynamic analysis, penetration testing, automated vulnerability scanning	OWASP ZAP, Burp Suite, Selenium	Rapid identification of vulnerabilities in integrated systems; automation of testing processes	Dependence on the accuracy of vulnerability databases; complex configuration
Deployment and Operations	Continuous monitoring, log analysis, real-time vulnerability assessment	SIEM systems, IDS, monitoring platforms (Splunk, ELK Stack)	Continuous security improvements; rapid incident response	Requires ongoing updates; high personnel qualification requirements

Integrating security testing at all stages of the software development lifecycle enables the creation of a multi-layered protection system that ensures timely vulnerability detection and remediation. Automating processes within CI/CD, distributed testing, and a well-established feedback system between development participants enhance the overall reliability and resilience of software products. This approach, supported by numerous studies, is essential for meeting modern security requirements in the rapidly evolving IT landscape.

Thus, the comprehensive inclusion of security testing in SDLC not only helps identify and address existing vulnerabilities but also prevents new ones from emerging, ensuring a high level of protection for information systems throughout their lifecycle.

4. Conclusion

The findings indicate that integrating security testing at all stages of the software development lifecycle is critically important for ensuring the reliable protection of information systems. The analysis of modern methods has shown that traditional approaches, such as functional testing, penetration testing, and static/dynamic code analysis, combined with innovative automation techniques and machine learning algorithms, enhance the accuracy and speed of vulnerability detection. Particular emphasis is placed on integrating security testing into CI/CD processes, enabling continuous monitoring and rapid response to emerging threats.

The examined model demonstrates the feasibility of establishing a multi-layered security system where automated tools, specialized scanners, and analytical algorithms operate in close coordination with software development and operational processes. Future research may focus on optimizing machine learning algorithms for predicting new types of vulnerabilities, expanding the functionality of automated testing systems, and further integrating security assurance into agile development methodologies. Such a comprehensive approach will contribute to the development of highly reliable and cyber-resilient software products capable of meeting the demands of the modern market.

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