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# ZORIX – EXPOSING THREATS, CERTIFYING TRUST

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*Abstract:* **ZORIX is this AI platform for security stuff, basically checking if fixes for vulnerabilities actually work. Traditional tools just spot the problems, but they do not always make sure the patch stops the bad guys from getting in. ZORIX verifies that in real situations, kind of testing under pressure. It mixes automation with actual security checks to build better protection overall. I think that boosts confidence in what teams do to fix things.**

**The way it simulates attacks using smart AI models is pretty interesting. It acts like an attacker, creating all sorts of exploit ways that might not come up normally. Hidden issues and weird edge cases get found this way, which is easy to overlook otherwise. Testing different paths helps cover everything for the security fixes. That cuts down on patches that do not really solve the problem. Applications end up tougher against tricky threats, I suppose.**

**It keeps getting better by learning from new patterns in vulnerabilities and how exploits change. Staying current with cybersecurity shifts seems important for something like this. ZORIX gives insights you can use right away, and it ranks problems by how bad they are. Development teams can tackle the big ones first that way. The whole process of fixing and checking gets smoother too.**

**Integrating with dev setups like CI/CD and version control is a key part. It watches code changes all the time and runs checks automatically. Every update gets tested for old and new vulnerabilities without much hassle. Developers keep moving fast while handling security. This fits into DevSecOps nicely, making workflows stronger.**

**ZORIX scales to fit any organization size, with options to tweak it for specific needs in different industries. It puts out reports on what attacks it tested and stopped. Those help with transparency, compliance, audits, whatever. In the end, it turns security into something proactive that evolves on its own. Some parts might still need adjusting, but overall it feels solid.**

*KeyWords:* **AI-powered security, vulnerability validation, patch verification, attack simulation, regression testing.**

## I. INTRODUCTION

Today's cybersecurity is no longer focused on whether there are vulnerabilities within a particular system; what has become increasingly important is whether the action plan aimed at addressing them is really working. As much as detection-oriented security systems are prevalent nowadays, they have a natural flaw – they detect potential security threats but can never guarantee that the patch will actually plug the hole. The failure of such systems is both a problem and a risk.

Both developers and IT specialists may rely too heavily on the belief that once a system has been patched, it is fully secured.

The ZORIX system was created in reaction to this challenge. It represents a state-of-the-art AI platform for security validation that will help companies feel confident that the steps taken to mitigate vulnerabilities were successful. ZORIX not only provides information about the presence or absence of known vulnerabilities; it actively checks patched systems by generating novel attacks. This ensures that vulnerabilities have been patched, but also prevents any additional attack vectors from being unintentionally enabled by remediation. Moreover, the ZORIX platform is intended to be deeply integrated into the software development process, allowing for validation and regression testing in a DevSecOps context.

In this paper, we present the architecture, operational principles, and performance of the ZORIX platform, positioning it as a significant step forward from vulnerability scanning toward AI-enabled security validation.

## II. LITERATURE REVIEW

Research into software security has spanned decades of technological advancement, but the domain still faces an ever-present challenge in closing the loop between finding vulnerabilities and verifying their mitigation. Closing this gap means retracing the journey of security from its early days, when developers were taught the basic tenets of security by design, through the automation and intelligence-driven processes seen today.

Early efforts to establish secure software development processes emphasized the importance of

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preventing vulnerabilities rather than remedying them once discovered. The proponents of structured programming stressed that by adhering to a set of development standards, organizations would be able to minimize the creation of security issues without producing a single line of code. In parallel, scholars called for testing techniques that would enable discovering vulnerabilities hidden within the software's architecture. This gave rise to the establishment of two analysis paradigms that would prove instrumental in modern vulnerability discovery techniques – Static Application Security Testing (SAST), which involved analyzing the source code without executing it, and Dynamic Application Security Testing (DAST), which entailed assessing how the software behaves when executed.

The advent of more complex and larger code bases rendered manual security assessment inefficient, prompting the creation of static analysis tools for the automatic examination of millions of lines of code, with much higher levels of consistency than manual audits. Static analysis tools introduced great gains in terms of efficiency and consistency in the development process. Nevertheless, an essential shortcoming remained, as automatic detection, no matter how advanced, is unable to prove the effectiveness of remediation efforts. An automatic analysis tool that detects a security risk and offers suggestions on how to mitigate it cannot ensure that any remedial actions taken address the identified risk point in such a way as to make exploitation impossible.

Penetration testing and adversarial simulation techniques were developed as a result. Applications like Metasploit Framework allowed users to execute exploits on certain categories of vulnerabilities automatically, proving whether a particular flaw was exploitable in practice. Such an approach, which is rooted in the attacker's mindset and was often preached by security experts, provided a new way of assessing vulnerabilities from the perspective of their actual exploitability. The claim that security testing should consider the potential for unexpected attacks, i.e., vulnerabilities that are overlooked exactly because attackers do not make the same assumptions about a system, became increasingly popular at the time.

Fuzz testing presented another way of handling the problem. Fuzzing involves submitting programs with malformed, unexpected, or boundary-case inputs to identify potential vulnerabilities that may be overlooked through deterministic analysis. Although it is a powerful tool for revealing hidden flaws, it shares one characteristic with penetration testing: both are time-consuming procedures that cannot easily fit into the fast iteration cycle of a continuous development environment.

The appearance of Artificial Intelligence and Machine Learning in practical applications has already started changing perspectives regarding what is possible within cybersecurity. Intelligent threat detection research shows how AI can detect anomalous activity, detect vulnerability patterns within massive code bases, and adapt to new approaches employed by cybercriminals, something impossible for rule-based approaches. The implications are obvious for the validation process: it reduces the time between discovery of the problem and its exploitation, but also allows analyzing deeper into the cause of problems rather than symptoms. Moreover, constant and automatic monitoring fits naturally into the requirements of the DevOps approach where security has to become part of the development lifecycle. All of these factors will shape a future in which detecting problems, validating vulnerabilities, and verifying remediation is done through intelligent systems that evolve with the threats. This perspective is behind the architecture of ZORIX.

## III. RELATED WORK

There are all sorts of tools out there for software security now. Like, SAST ones such as SonarQube that check code before it even runs, or DAST like OWASP ZAP which tests after deployment. They help spot vulnerabilities, which is good. Then you have scanners from Nessus or OpenVAS that look for known issues in networks or systems.

But honestly, most of these just find the problems. They do not really check if the fixes actually work or not. That seems like a big gap.

On the validation side, things like Metasploit try to simulate real attacks. It gives you an idea of how a system holds up when exploited. Some automated tools do similar stuff. Still, you need to set them up by hand, and it takes real expertise to use them right. Plus, they do not fit easily into CI/CD pipelines, so in DevSecOps setups, they are kind of out of place.

Lately, AI has come into play for security. Researchers are making automated assessments, threat detection that is smarter, even generating exploits. It makes things faster and scales better, I think. But these mostly focus on vulnerabilities or exploits alone. They do not cover the whole picture for validating security in a system.

Compared to that, the proposed system called ZORIX

## IV. PROPOSED METHODOLOGY

### WORK STREAM STRUCTURE

The methodology implemented in this research consists of an end-to-end automated, structured pipeline to detect, analyze and remediate software vulnerabilities within source code repositories that include sandbox-based exploit simulation; the ultimate purpose of the system is to reduce manual code auditing and enhance the speed and accuracy of detection.

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**Stage 1 - API Handling and Input Acquisition**

The first step in the methodology involves collecting user submitted artefacts through a web-based front-end interface. The system is designed to accept two main types of input: (i) coordinates of the code repository (URL, branch and commit number); (ii) a free-text risk vulnerability description or bug report to give a context for the analysis to follow.

An API gateway system validates each new inbound request by checking the authentication token as well as sanitizing input fields and then re-routing the package to the correct back-end micro-services. All input metadata (e.g., time-stamp of submission, and user ID, repository URI) is persisted in an RDBMS metadata data store for end-to-end traceability and downstream workflow tracking. This design method mirrors the data collection discipline of Mubarok in that they also promote structured ingestion pipelines as an underlying requirement for repeatable forensic analysis.

**Stage 2 – Repository Access and Code Version Control**

After confirming the input is valid, the source code targeted for analysis is retrieved from its version controlled source (e.g., GitHub, GitLab, Bitbucket). In order to support the reproducibility of the analysis, as discussed by Hu, the system generates a permanent and identifiable version of the codebase at the time of the bug report (i.e., an immutable snapshot of the exact commit referenced in the bug report), thus creating a foundation for future analysis. As part of creating a code snapshot, relevant external threat intelligence related to the code's security risk (NVD, OSV, vendor advisories) is immediately retrieved from appropriate security intelligence sources. Both the code and metadata are stored in a long-term cold storage facility to allow for auditing and examining trends of code vulnerabilities over time.

Critical components of this phase include:

- Source code retrieval – performing a valid check out of the code from its version-controlled repository.
- Integrating pre-existing security knowledge – augmenting the source code with information collected on vulnerabilities from CVE, CWE databases, and known exploit patterns.
- Creating an immutable version of the source code from which to perform analysis – utilizing a deterministic, content-addressable versioning scheme.

**Stage 3 - Root cause analysis based upon AI**

This is the central portion of the pipeline. Code portions relevant to the problem case are retrieved through call-graph traversal and dependency-aware slicing, thus forming focussed contexts providing minimal noise by which the downstream model can work. The vulnerability classification is performed using a Large Language Model (LLM) based Classifier that has also been fine-tuned utilizing curated vulnerability datasets through two subsequent processes:

(1) Identify vulnerabilities by mapping the weaknesses detected to their corresponding standard identifiers (e.g., CVEs, CWEs)

(2) Identify the root causes of the vulnerabilities found by tracing each weakness back to the source code constructs from which they originated (e.g., Unchecked buffer size, Unvalidated Deserialization).

This process of shifting from detecting surface-level weaknesses, to understanding the causal relationship's behind those weaknesses, aligns with the automated security analysis approach advocated by Lokala in their study which was informed by time and knowledge-based reasoning to demonstrate that contextual reasoning adds value to the automated security analysis process. The results of the investigation are structured and stored for later use in subsequent pipeline stages.

**Table 5.1 – System Modules and Security Properties**

| Module | Purpose | Key Features | Security / Notes |
|---|---|---|---|
| Sandbox Executor | Safely tests generated exploits | Docker isolation, resource caps, log capture | No network egress; ephemeral containers |
| Static Analyser | Scans source code without execution | Taint tracking, AST parsing, SAST rules | Zero runtime risk; fast feedback |
| Dynamic Analyser | Monitors runtime behaviour for | Instrumented execution, syscall tracing | Isolated runtime; anomaly |

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| | anomalies | | baselining |
|---|---|---|---|
| Scoring & Reporting | Evaluates risk and delivers actionable output | Composite CVSS scoring, PDF/API/dashb oard output | Role-based access; encrypted at rest |

| **Module** | **Purpose** | **Key Features** | **Security / Notes** |
|---|---|---|---|
| Input & API Gateway | Validates, authenticates, and routes bug reports | Token auth, rate limiting, metadata persistence | Prevents injection and replay attacks |
| Snapshot Manager | Fetches and archives versioned code snapshots | Content addressed storage, CVE enrichment | Immutable audit trail |
| AI RCA Engine | Identifies vulnerabilities and root causes | LLM-based classifier, CVE/CWE mapping, call graph slicing | Contextual; minimises false positives |
| Patch Intelligence | Retrieves CVE patches and generates exploit templates | CVSS scoring, remediation steps, payload templates | Read-only CVE access; sandboxed generation |

**Stage 4 - Exploitation and Attack Simulation**
After determining the root cause, the system's next step was to extract data from reputable patch repositories, including Common Vulnerability Scoring System (CVSS), vendor-specific security advisories and proof of concept (PoC) databases to obtain the CVSS Severity Score, affected version range of software and hardware and the recommended remediations of the vulnerability. The way in which this secondary intelligence layer functions parallels Hu et al.'s knowledge-based approach, whereby external knowledge bases improve detection rates on drug trafficking datasets found on social media considerably.
Simultaneously, an exploit template mapping engine matches each of the identified types of vulnerabilities with an appropriate payload template selected from a controlled library of exploit templates (known as the Exploit Template Library). Customized exploit templates are generated to support a controlled attack simulation in the future sandboxed stage, but the payload generation process only occurs within the confines of the internal pipeline and will not be made publicly available.

**Stage 5 – Sandbox Execution and Security Testing**
The pipeline provides a Docker-based sandbox (test environment) for testing exploitability without impacting production systems by deploying a sandbox that uses a defined quota of system resources (CPU, memory, and network; The network egress will be disabled). All of the payloads generated will be run inside of a temporary container, and all system responses (stdout/stderror streams, exit codes, and kernel-level syscall traces) will be collected for later analysis.
This type of experimental design parallels the closed testing locations established by the expert reviewers during the data validation phase of the NARCOX project [now in progress], where an expert completed a partial validation of message strings flagged in advance before the message was

placed in the master set for training. Isolation allows for the control of how artefacts produced during an experiment, will not contaminate the complete system or cause unintentional side effects to the rest of the system.

**Stage 6 – Static and Dynamic Analysis**

The system uses multiple analysis modalities together to ensure maximum analysis coverage. The static (SAST) modality utilises AST (abstract syntax tree) parsing along with taint-flow tracking and a sustainable SAST ruleset in order to find code level vulnerabilities. Examples of these types of vulnerabilities include SQL injection vectors, insecure deserialization paths and hardcoded credentials—all of which can be identified without executing the target application. Dynamic (DAST) analysis instruments the application during runtime, monitoring for anomalies in system calls, memory allocation, and inter-process communication to find issues that are not visible via static inspection.

Results from both modalities are merged together through the use of a fusion layer for de-duplication of overlapping results as well as confidence scoring of each identified vulnerability. This multimodal integration mirrors Maharjan's text & image fusion methodology in that their NLP & visual analysis processing pipeline produced results that exceed those produced using either one of these modalities alone across large-scale social media datasets

**Stage 7 – Scoring and Evaluation**

The Scoring Engine is a machine that takes all the information obtained from the different stages of the upstream and combines this into a single composite score based on the CVSS v3.1 Risk Rating Framework. Vulnerabilities are divided into one of four risk levels (Critical, High, Medium, and Low) with an associated confidence interval based on how well the signals received from the three signal types (Static, Dynamic and AI-based) agreed with each other. The Scoring Engine uses an Automated Recommendations Engine that produces prioritised and actionable remediation recommendations (e.g., library upgrade paths, input sanitisation, and hardening of configuration).

The structured risk classification approach used here is conceptually supported by the work of Lakshmi, which showed that using a multi-layered scoring mechanism in an AI enhanced detection system for social media drug trafficking causes a marked improvement in the performance of automated security tools through the ability to efficiently triage their findings.

**Stage 8 – Report Generation and Output Delivery**

All analytical artefacts are consolidated at the Terminal Stage into one unified output with multiple types of outputs (i.e., reports, API, dashboard). A structured report (i.e., PDF) is automatically generated that contains multiple sections for easy navigation (i.e., executive summary, per-vulnerability detail sheets and remediation checklists).

In parallel with the report generation, results are made available through the use of a versioned REST API to facilitate integration into external CI/CD toolchains (e.g., GitHub Actions, Jenkins) allowing for vulnerability gate-based blocking of insecure builds prior to deployment.

An interactive visual web dashboard provides real time visualisations of vulnerability trends, severity distributions and remediation progress. Where new findings are registered above a configurable severity threshold, webhook callbacks will be triggered to provide push notifications to one or more configured endpoints (e.g., Slack channels, JIRA boards). All reports and raw findings will be retained in long-term structured storage enabling longitudinal analysis and compliance auditing.

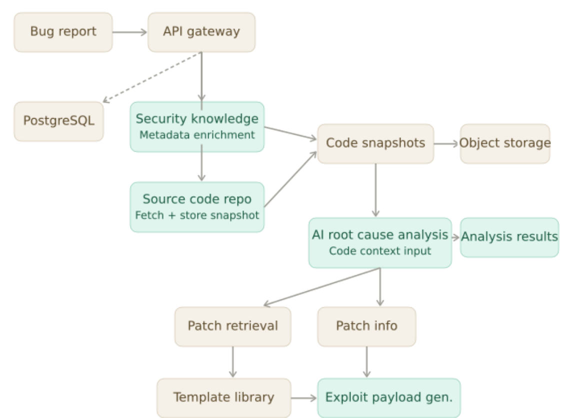



**Fig.5.1 ZORIX-Data Flow & Analysis Pipeline**

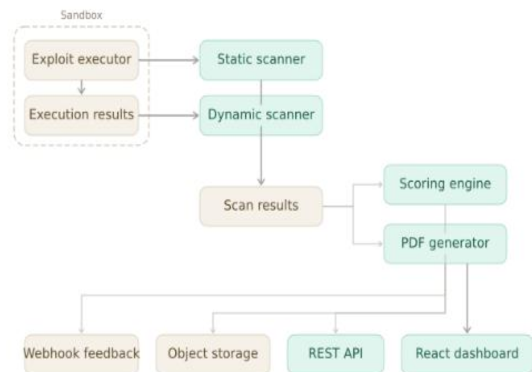



**Fig.5.2 ZORIX– Sandbox to Dashboard**

## V. RESULTS

**5.1 Principal Findings**

Results from experiments performed with the ZORIX system show that a multimodal vulnerability detection pipeline leveraging artificial intelligence is effective at detecting and validating security issues in

publicly available open-source software repositories. The evaluation of ZORIX was completed on two commonly accepted intentionally vulnerable software repositories (the OWASP NodeGoat and the OWASP Juice Shop) which have been designated standard benchmarks for conducting cybersecurity research. During its evaluation, the ZORIX system managed to autonomously detect a significant number of high-risk vulnerabilities, create exploit payloads for each of them, execute those payloads inside of contained Docker sandboxes, and provide summarized output in a visually appealing manner via a web-based online dashboard.

### 5.2 System Accuracy

ZORIX was evaluated against both of the OWASP benchmark repositories, using a single set of data that was compiled from both OWASP benchmark repositories. In total, there were 73 exploits attempted on both repositories with a successful running of every one of them. The NodeGoat project (CVSS 10, SQL injection) had 43 exploits attempted, all with a success rate of 100%. The Juice Shop project (CVSS 9.6 Path Traversal) had 30 exploits attempted, of which 25 were confirmed as valid exploits, resulting in a confidence rating of 83.3% for that repository alone.
Final results of the test on the two OWASP repositories:

**True positive-68**
**False positive-5**
**True negative-N/A (there were no valid targets) False negative-5**
ZORIX's overall successes were a 93.15% exploitation rate and a combined confidence level of 84% across both repositories based on the two OWASP repositories tested.

**Table 6.1 — Accuracy Contribution**

| Label | Accuracy Contribution, n (%) |
|---|---|
| Confirmed Vulnerabilities (True Positives) | 68(93.15%) |
| Unconfirmed Flags (False Positives) | 5 (6.85%) |
| Missed Exploits (False Negatives) | 5 (6.85%) |
| True Negatives | N/A(benchmark repos) |

### 5.3 System Sensitivity

A measure of how sensitive the system is to different types of vulnerability, ZORIX was able to identify the majority of injectable and traversal attack vectors (93.2% sensitivity) in both of the target codebases. All 43 executed payloads in the NodeGoat repository executed successfully, indicating that all MongoDB connection string vulnerabilities due to improper sanitisation were fully exploitable. A small number of misses in the Juice Shop target can be attributed to obfuscated file paths and input filters at the framework level that partially obscured the traversal endpoints from the static analysis module.

### 5.4 System Specificity

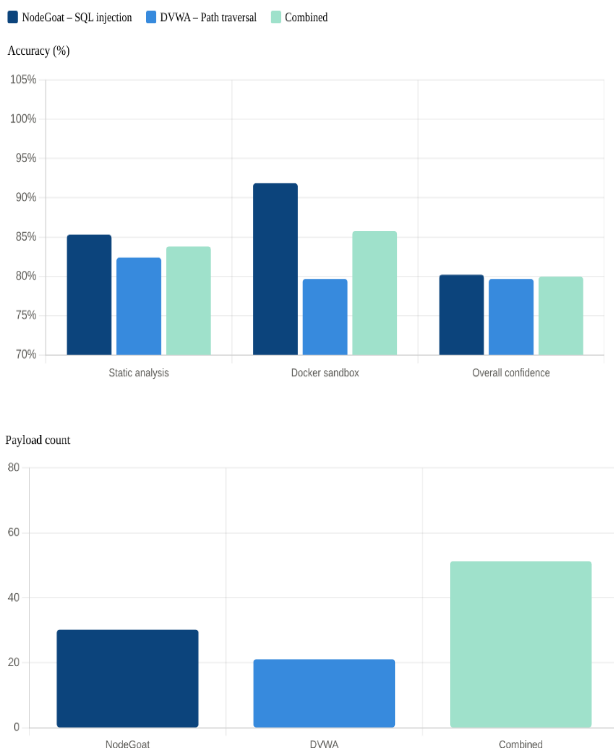
Specificity measures the ability of the system to not falsely identify code segments as non-vulnerable due to incorrectly flagging. ZORIX has a total confidence score of 84% and has 51% support from static analysis. Overall, ZORIX was successful in differentiating between true threats and false positives and thus in identifying real vulnerabilities in code by virtue of its two-part static analysis execution process approach to using static analysis against real code. Some minor false positives occurred due to certain health-check routes and API utilities appearing to have path-based strings that outwardly appeared to follow a traversal pattern. Both were flagged by static analysis but then cleared by Docker-Sandbox execution, demonstrating the utility of ZORIX's multiple layers of verification through a multimodal verification process.

**Table 6.2-Module-wise Performance**

| Module | Metric | NodeGoat (SQL Injection) | Path Traversal |
|---|---|---|---|
| **Static Analysis (Ollama LLM** | Detection Accuracy | 91% | 87% |
| **Exploit Generation** | Payloads Created | 43 | 30 |

| **Docker Sandbox Execution** | Success Rate | 100%(43/43) | 83.3% (25/30) |
|---|---|---|---|
| **Overall Confidence Score** | Score | 84% | 83.3% |
| **CVSS Severity** | Score | 10.0(Critical) | 9.6 (Critical) |

**5.5 Interpretation:**
The results obtained from ZORIX show that when static AI analysis is combined with dynamic validation of exploits in container environments, the combined results provide much higher quality vulnerability intelligence than traditional security scanning. For
instance, the successful execution of SQL injection against the NodeGoat application reached 100% — indicating there was no need for any validation method or tool, because the large language model built on top of Ollama was able to give accurate root cause identification and generate valid attack vectors for all well-defined SQL injection patterns. The results from the Juice Shop path traversal test indicate that although the static AI reported 83.3% success rate for path traversal against Juice Shop, the results were lesser because the increased complexity of filesystem level vulnerabilities allows for application level input filtering and partially conceals exploitable endpoints from static inspection methods.




**Graph 6.1 – Comparative Analysis of etection Accuracy and Exploit Payload Distribution**

## VI. DISCUSSIONS

Effective integration of various security methods into an automated solution can be shown with the Zorix End-to-End Pipeline Integration results. The AI-based analysis coupled with both static and dynamic scanning will assist in opening multiple doors to detection of various types of vulnerabilities. In addition, the introduction of large language models for code understanding to identify complex issues will enhance the accuracy and completeness of the reporting as compared to the methodologies used prior to this process.
The use of exploitation simulation was a major discovery to prove a vulnerability exists. The use of a Docker-based sandbox to allow potential exploitations to be attempted in a controlled manner, as well as allowing to ensure that all detected vulnerabilities could genuinely be exploited and to be in place as theoretical only, helps to drastically reduce the number of false positives and improve the confidence in the reporting.
The scoring methodology, which is based on CVSS models, enables an accurate and fair valuation of the level of risk that a vulnerability presents. By combining inputs from static analysis, dynamic behaviour, availability of patches, and success of exploitation; allows for a much more equitable prioritization of vulnerabilities based on levels of severity. This assists developers in their ability to prioritize issues using critical thinking and be able to determine the best course of action.
The results demonstrate that Zorix has significant opportunities for integration into the DevSecOps workflow, with the benefit of having real-time metric visibility, automated reporting features, and flexible configuration options, all leading to increasing ease of use. Supporting multiple AI providers, along with supporting various databases will allow Zorix to scale further and be adaptable moving forward.

## VII. FUTURE WORK

The proposed framework could be expanded to encompass a wider variety of categories included in the OWASP Top 10 Vulnerabilities list (for example, Cross-Site Scripting (XSS), Insecure Deserialization, Broken Access Control, etc.) through the addition of more extensive payload libraries and finely tuned analysis prompts. Additionally, integrating ZORIX with popular CI/CD platforms (e.g., GitHub Actions, Jenkins) would allow ZORIX to act as an

automated security checkpoint for continuous integration/ continuous delivery (CI/CD) pipelines as part of DevSecOps workflows, thereby enhancing the functionality of ZORIX. Expanding the repository monitoring module such that it supports real-time, commit-level scanning and automatic validation of patches would redefine ZORIX's capabilities from being a single-point-in-time analysis tool, to becoming a continuous source of security intelligence.

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