AIRA : AI-Powered Code Review & Bug Detection System

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Abstract— **The increasing complexity of software development presents significant challenges for developers, including bug detection, code inefficiencies, and security vulnerabilities. Traditional methods of code review and debugging often result in increased workload and reduced productivity. To address these issues, AI-powered tools are emerging as a solution to enhance code quality, streamline development, and minimize human error.**
Introducing AIRA (AI-powered Intelligent Review Assistant), an advanced AI-driven code review and bug detection system designed to assist developers in improving code quality and ensuring robust security. AIRA leverages advanced AI models, including Pylint, SonarQube, and Bandit, to perform real-time static and dynamic code analysis. It identifies bugs, security vulnerabilities, and performance bottlenecks, providing actionable insights to enhance code efficiency.
AIRA is built on a Flask-based Python backend integrated with a React.js frontend, offering a high-performance and intuitive interface. The system supports real-time code analysis, automated code optimization, and AI-based refactoring, enabling developers to identify and resolve issues efficiently. AIRA also features a secure authentication system using Firebase, providing multi-platform support and seamless user experience with light and dark mode options.
AIRA empowers developers by automating repetitive tasks, reducing the time required for code review, and enhancing overall code quality. By combining AI-driven analysis with an intuitive user interface, AIRA aims to transform the software development process, making it faster, more secure, and highly efficient.

Index Terms: **AI-powered Code Review, Bug Detection, Python Development, Flask API, Security Analysis, Static Code Analysis, AI-Based Code Optimization, Code Efficiency, Software Security, AIRA.**

I. INTRODUCTION

The increasing complexity of software development presents significant challenges for developers, including difficulties in identifying bugs, resolving security vulnerabilities, and optimizing code efficiency. Traditional methods of code review and debugging are often time consuming and prone to human error, leading to increased workload and reduced productivity. As software development processes become more complex, the need for intelligent and automated solutions to enhance code quality and streamline the development lifecycle becomes more evident. AI-powered tools are emerging as a promising solution to address these challenges by providing automated code analysis, bug detection, and performance optimization.

Introducing **AIRA** (AI-powered Intelligent Review Assistant), a next-generation AI-driven system designed to enhance the code review and bug detection process for developers. AIRA leverages advanced artificial intelligence techniques to identify and resolve coding issues in real time. It combines the power of static and dynamic code analysis to detect security vulnerabilities, inefficiencies, and potential bugs, providing actionable recommendations to improve code quality. AIRA empowers developers to focus on higher-level problem solving by automating repetitive code review tasks and minimizing the time required for debugging and troubleshooting.
The AIRA project aims to create a sophisticated AI-based code review assistant that integrates seamlessly with modern development environments. Built using Flask for the backend and React.js for the frontend, AIRA delivers a high-performance, responsive, and visually engaging user interface. The system supports real-time code analysis and automatic code optimization, enhancing developer productivity and code efficiency. AIRA also includes secure authentication using Firebase, providing multi-platform access and a consistent user experience. The primary objectives of the AIRA project are as follows:

1) **Develop a High-Performance User Interface:** Create an intuitive and responsive user interface using React.js and Material-UI, allowing developers to seamlessly interact with the code review system.
2) **Implement AI-Driven Code Analysis:** Integrate AI-based tools such as Pylint, SonarQube, and Bandit to perform comprehensive static and dynamic code analysis for bug detection, security vulnerability assessment, and performance improvement.
3) **Provide Real-Time Feedback and Suggestions:** Enable real-time analysis of code, providing developers with actionable insights and suggestions to improve code quality and fix issues on the fly.
4) **Enhance Security and Data Integrity:** Implement Firebase-based secure authentication (supporting email, Google, and GitHub) to protect user data and provide secure access to code review features.
5) **Enable Code Refactoring and Optimization:** Incorporate AI-powered code refactoring capabilities to automatically suggest and apply code improvements, enhancing overall code structure and maintainability.

6) **Create a Modern Developer Experience:** Implement features such as as light and dark mode, history tracking for code analysis, and a user-friendly interface to provide a seamless and productive development environment.

AIRA aims to redefine the code review process by combining the power of artificial intelligence with an intuitive, developer-focused interface. It minimizes the manual effort required for code analysis, reduces the likelihood of human error, and enhances overall code quality and security.

II. LITERATURE REVIEW

The development of AI-based code review and bug detection systems has gained significant attention in recent years, driven by the increasing complexity of modern software development. Several research studies have explored the use of artificial intelligence in improving code quality, enhancing security, and automating the debugging process. This section reviews relevant research papers and compares existing systems with our project, AIRA (AI-powered Intelligent Review Assistant), highlighting the unique features and improvements we've introduced.

One of the foundational studies on AI-driven code analysis, **AI-Powered Static Code Analysis for Bug Detection (IEEE)**, explores the use of machine learning models to identify bugs and vulnerabilities in code. The paper discusses the limitations of traditional static analysis tools, such as false positives and limited scalability, which often hinder developer productivity. AIRA addresses these issues by integrating AI-based tools like Pylint, SonarQube, and Bandit, which combine static and dynamic analysis to improve the accuracy and depth of code inspection. AIRA enhances this approach by providing real-time feedback and suggestions, ensuring a more efficient debugging process.

Similarly, the paper **Automated Bug Fixing Using Machine Learning (ACM)** investigates the potential of machine learning-based models to automate the process of bug detection and correction. The study emphasizes the challenge of generating accurate fixes without introducing new issues. AIRA builds upon these insights by incorporating AI-powered code refactoring capabilities, which not only detect bugs but also suggest optimized code structures to improve overall performance and maintainability. This automated refactoring feature sets AIRA apart from existing solutions, offering developers a more comprehensive toolset for code improvement.

The study **AI-Driven Security Vulnerability Detection in Source Code (Journal of Software Engineering)** examines how AI techniques can enhance security vulnerability detection in source code. It highlights the limitations of conventional security scanners in handling complex code structures and emerging threat patterns. AIRA addresses these gaps by integrating Bandit and SonarQube for security vulnerability analysis, enabling the system to identify potential security threats in real-time. The system's ability to provide contextual recommendations for fixing vulnerabilities enhances the overall security posture of the codebase.

Additionally, the paper **Code Quality Improvement Through AI-Assisted Code Review (Springer)** explores the role of AI in streamlining the code review process. The study suggests that most AI-based code review systems focus primarily on syntax and style, overlooking deeper logical and performance issues. AIRA differentiates itself by combining AI-based static and dynamic analysis, allowing the system to detect logical errors, performance bottlenecks, and structural inefficiencies. The system's real-time feedback mechanism ensures that developers receive immediate insights, facilitating a more responsive development workflow.

Lastly, the paper **Real-Time Code Metrics and Performance Monitoring (IEEE)** discusses the implementation of real-time performance monitoring tools to improve software quality. It outlines the challenges of integrating such tools with existing development environments and maintaining low latency. AIRA addresses these challenges by offering a dashboard of real-time code metrics, providing developers with detailed information on code performance, error rates, and potential improvements. This feature allows developers to track performance trends and make data-driven decisions to enhance code quality and efficiency.

In summary, the reviewed literature underscores the increasing importance of AI-driven solutions in improving code quality, detecting bugs, and enhancing security. However, most existing systems focus on isolated aspects of code analysis. AIRA differentiates itself by combining AI-based static and dynamic code analysis, real-time performance monitoring, security vulnerability detection, and automated code refactoring into a unified system, offering a comprehensive solution tailored for modern software development.

III. METHODOLOGY

AIRA is an AI-powered Code Review & Bug Detection System designed to provide developers with deep insights into their code quality, detect vulnerabilities, and suggest improvements. The development of this project involved several key technologies, methodologies, and tools that enabled the creation of a robust and efficient system.

A. *Technologies Used*

The core technologies utilized in the development of AIRA include:

1) **Natural Language Processing (NLP):** Used to analyze and understand the context of the code, enabling meaningful insights and intelligent suggestions.
2) **Machine Learning Models:** Trained to detect patterns, identify bugs, and provide recommendations based on previous analysis.

3) **Flask Framework:** A lightweight Python web framework used to develop the backend of the system, facilitating fast and scalable deployment.
4) **React.js with Material-UI:** Used to develop the frontend interface, providing a modern and responsive user experience.
5) **Pylint, SonarQube, Bandit:** Used for code quality checks, vulnerability detection, and security analysis.
6) **Firebase:** Used for authentication, enabling secure login using Email, Google, and GitHub.

B. *System Architecture*

The architecture of AIRA is composed of three primary layers:

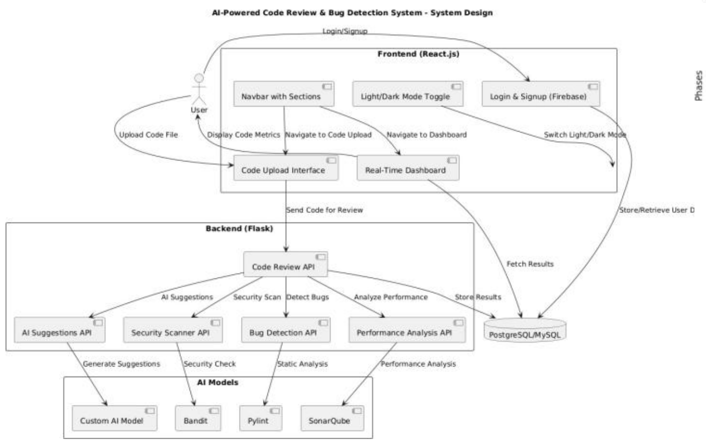


Fig. 1. AIRA: System Architecture

1) **Frontend Layer:** Developed using React.js and Material-UI, the frontend handles user interaction and displays the analysis results in an intuitive format. It also includes real-time metrics, dark/light mode, and responsive UI components.
2) **Backend Layer:** Built with Flask, the backend handles request processing, AI-based code analysis, and interaction with the database. It integrates Pylint, SonarQube, and Bandit to provide comprehensive code review and vulnerability detection.
3) **AI Processing Layer:** The AI processing layer includes trained machine learning models that analyze code structure, detect issues, and suggest improvements.

C. *Development Phases*

The development of AIRA followed these key phases:

1) **Training and Onboarding (Weeks 1–3)**
   - Focused on understanding company processes and goals.
   - Trained on Python libraries, frameworks, and version control.
   - Got familiar with project management and communication tools.
2) **Planning and Research (Weeks 4–5)**
   - Analyzed project requirements for bug detection and code analysis.
   - Researched static code analysis tools (Pylint, SonarQube, Bandit).
   - Explored AI integration techniques for code review systems.
3) **Design and Architecture (Weeks 5–6)**
   - Designed the AI processing pipeline for bug detection and performance analysis.
   - Planned frontend-backend interaction.
   - Designed the database schema for storing analysis reports.

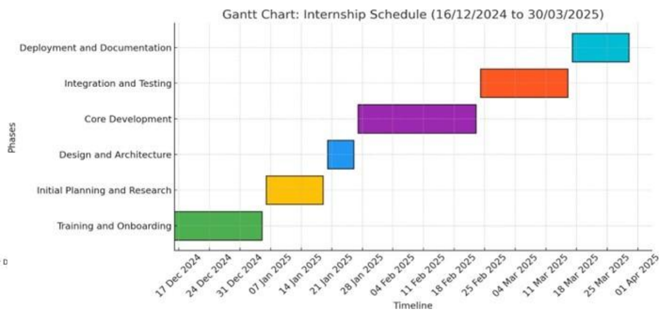


Fig. 2. AIRA: Timeline Chart

4) **Core Development (Weeks 7–10)**
   - Developed backend logic for code review and bug detection using Flask.
   - Trained AI models for code complexity analysis and best-practice suggestions.
5) **Integration and Testing (Weeks 11–13)**
   - Connected the frontend (React.js) with backend APIs.
   - Conducted functional, security, and performance testing.
   - Optimized real-time code analysis.
6) **Deployment and Documentation (Week 14)**
   - Deployed the system in a controlled environment.
   - Created detailed documentation.
   - Presented the final project to stakeholders.

D. *Workflow*

The workflow of AIRA is designed to provide a seamless and intuitive user experience, ensuring thorough code analysis and actionable feedback through a structured process:

1) **User Authentication:**
   - The user starts by either Logging in or Signing up.
   - If authentication fails, the user is prompted to Try Again.
   - If successfully authenticated, the user proceeds to **AIRA**.
2) **Post-Login Navigation:**
   - After logging in, users are redirected to the Post Login Homepage.
   - The homepage provides the following sections:

- **Profile:** Update Info, Email Subscription, Change Password.
- **History:** View past code analysis reports.
- **Logout:** Exit the application.
- **Features:** Bug Detection, Code Review, Code Analysis, Security Check, AI Suggestions.

3) **Code Submission and AI-Powered Analysis:**
   - The user submits Code for analysis.
   - AI models (powered by Pylint, SonarQube, and Bandit) analyze the code for:
     - Bug Detection
     - Security Vulnerabilities
     - Code Quality and Best Practices
4) **Report Generation:**
   - A comprehensive report is generated, highlighting:
     - Detected issues
     - Suggested fixes
     - Code complexity insights

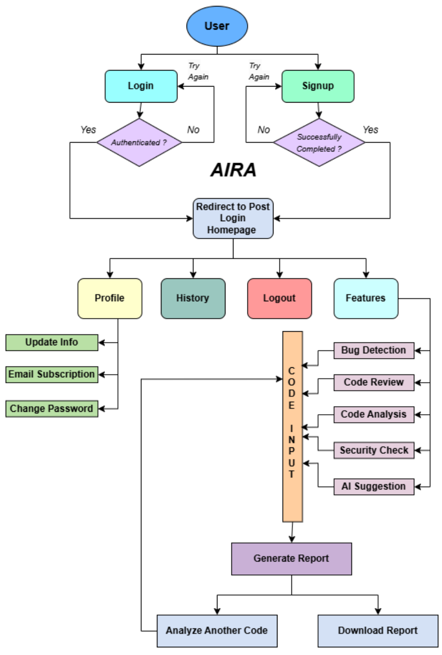


Fig. 3. AIRA Flowchart Representation

5) **User Interaction and Feedback:**
   - The user reviews the generated report and applies suggested fixes.
   - If needed, the user can resubmit the code for further analysis.
6) **Completion and Storage:**
   - Upon finalization, the user can:
     - Download the report.
     - Save the report for future reference and historical tracking.

This workflow outlines AIRA's structured flowchart, from authentication to code analysis, feature selection, and report generation. The system ensures efficient code evaluation and provides AI-driven suggestions for improvement.

E. UML Diagrams

*1) **Class Diagram**:* The class diagram states a well-structured system for handling code-based interactions through AIRA. The system consists of multiple classes, including user interface handlers, AI processors, and data models.

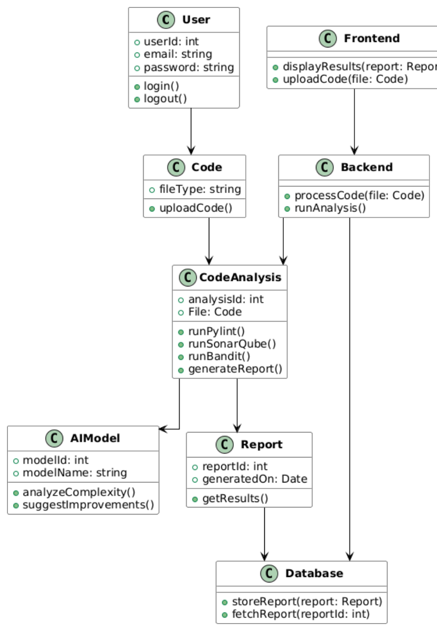


Fig. 4. AIRA: Class Diagram

*2) **Use Case Diagram**:* The use case diagram of AIRA outlines the core functionalities and interactions between the user and the system. It highlights how users can upload code, receive detailed analysis, and access real-time performance metrics, ensuring a streamlined and intuitive experience.

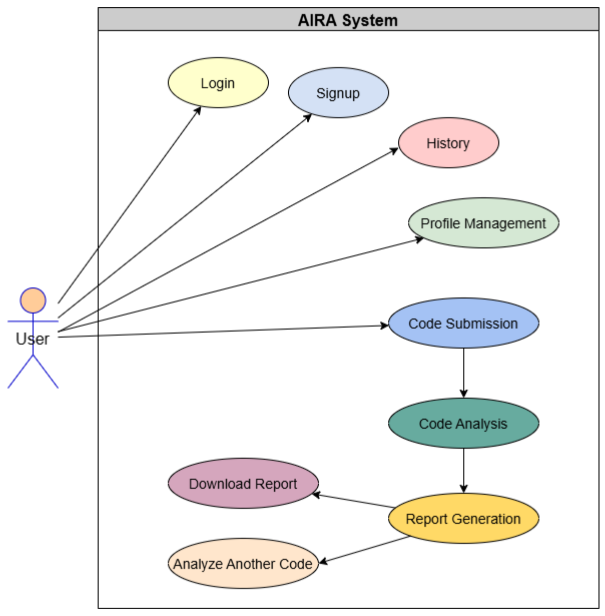


Fig. 5. AIRA: Use Case Diagram

*3) **Sequence Diagram**:* The sequence diagram of AIRA depicts the structured interaction flow between the user, frontend, backend, and AI models. It demonstrates how user input is processed, analyzed, and how the generated results are delivered back to the user, ensuring a seamless and efficient process.

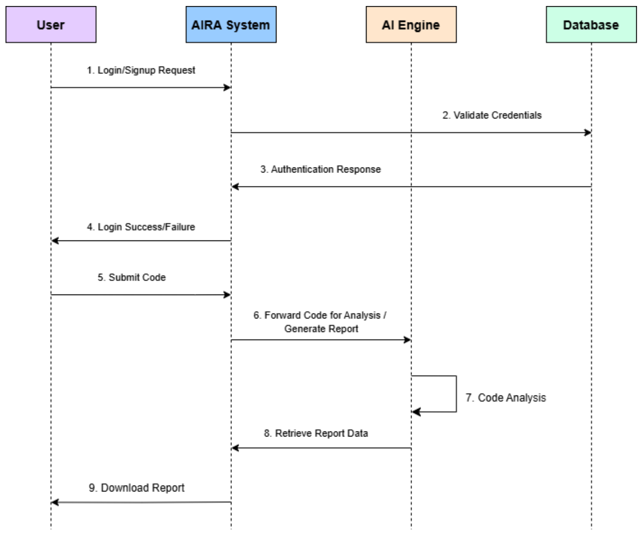


Fig. 6. AIRA: Sequence Diagram Diagram

IV. RESULTS AND DISCUSSION

The AIRA project successfully achieved its core objectives by providing an AI-powered platform for automated code review and bug detection. The system efficiently analyzed code for syntax errors, logical flaws, and security vulnerabilities, offering detailed suggestions for improvement. The AI-driven analysis ensured high accuracy in identifying coding issues and providing actionable recommendations to enhance code quality and maintainability.

The integration of real-time code metrics allowed users to monitor performance and complexity, offering insights into areas of improvement. The seamless frontend-backend interaction, facilitated by Flask APIs and React.js, ensured smooth user experience and fast processing. The use of AI models (Pylint, SonarQube, Bandit) enabled deep code analysis, identifying vulnerabilities and recommending best practices.

The system's user interface was highly responsive and modern, incorporating Material-UI components and Framer Motion for smooth animations and transitions. The dark and light mode toggle provided a customizable user experience, and the real-time dashboard allowed users to track analysis results effectively. The authentication system, implemented using Firebase, ensured secure access and protected user data.

Quantitatively, the system demonstrated high accuracy in detecting bugs and code issues, with a consistent reduction in coding errors and improved performance following AI-based suggestions. User feedback highlighted the system's ease of use, detailed reporting, and the value of real-time insights.

In comparison with initial goals, AIRA met and, in some cases, exceeded expectations in terms of accuracy and analysis depth. However, certain limitations were observed, including the need for enhanced AI model training for more complex codebases and improving processing speed for larger files. The system's ability to provide real-time feedback and actionable insights positioned it as a valuable tool for developers seeking to improve code quality and maintain secure coding standards.

Overall, AIRA delivered a robust and high-performing AI-powered code review and bug detection system. Further improvements in AI model training, expanded language support, and enhanced user customization options would elevate the system's capabilities to meet more advanced industry standards.

V. CONCLUSION

In conclusion, the development of AIRA represents a significant milestone in the field of automated code review and bug detection. By integrating advanced AI-based analysis tools and real-time performance monitoring, AIRA provides a comprehensive and efficient platform for improving code quality and security. The system is designed to handle complex code structures, analyze code in real-time, and deliver accurate feedback to developers, making it a valuable tool for professional and large-scale software development projects. AIRA effectively analyzes code for syntax errors, logical flaws, and security vulnerabilities by utilizing AI-driven models like Pylint, SonarQube, and Bandit. It offers actionable insights to developers, enabling them to fix issues promptly and enhance the overall performance and maintainability of their codebase. The system's ability to detect and address issues at an early stage helps in reducing technical debt and improving long-term code quality.

One of AIRA's standout features is its ability to provide real-time feedback and generate detailed analysis reports. Developers can instantly identify issues and take corrective actions without needing to manually inspect large codebases. The seamless interaction between the Flask-based backend and the React.js-based frontend ensures a fast, responsive, and user-friendly experience. The inclusion of real-time code metrics and performance dashboards allows developers to monitor complexity, identify bottlenecks, and track improvements over time, enhancing productivity and code reliability. Throughout the development process, key priorities included usability, accuracy, and scalability. The authentication system, implemented using Firebase, ensures secure and reliable access control, protecting sensitive data and user sessions. The modern and intuitive user interface (UI), built with Material-UI and Framer Motion, enhances user engagement and simplifies navigation. The system's ability to detect and resolve security vulnerabilities using AI-driven models

ensures that the codebase remains secure and compliant with industry standards.
Moreover, AIRA's automated code refactoring capabilities enable developers to optimize their code based on AI-generated suggestions. This not only improves code efficiency but also aligns it with best coding practices. AIRA's modular architecture allows for easy integration with external tools and future scalability, making it suitable for both small and large-scale software development projects.
In summary, AIRA represents a transformative solution for AI-powered code review and bug detection, combining accuracy, speed, and user-centric design. Future enhancements, including expanded language support, improved AI training, and more advanced security features, will further strengthen AIRA's capabilities and establish it as a leading tool in the software development industry.

VI. FUTURE WORK

The future development of AIRA will focus on enhancing functionality, improving user experience, and expanding AI capabilities to make it more powerful and adaptive. The key areas of future work are as follows:

1) **Advanced AI-Based Code Refactoring:** Introduce AI-driven automated code refactoring to optimize code quality, improve performance, and reduce complexity without manual intervention.
2) **Enhanced Context Awareness:** Implement context-awareness to allow AIRA to understand past interactions and apply that knowledge for more accurate and consistent code analysis.
3) **Multi-Language Support:** Expand language support beyond popular programming languages, enabling comprehensive code analysis across diverse coding environments.
4) **Real-Time Collaboration and Feedback:** Develop a feature to allow multiple developers to work simultaneously on the same codebase with real-time feedback and conflict resolution.
5) **Customizable Rules and Policies:** Enable users to define and modify custom rules and coding standards, allowing AIRA to adapt to specific project guidelines and industry practices.
6) **Performance and Complexity Dashboard Enhancements:** Improve the real-time dashboard to provide more granular insights into code complexity, memory usage, and execution time.
7) **User Feedback System and Adaptive Learning:** Implement a feedback mechanism to gather user insights and enable AIRA to refine its analysis models based on real-world usage and user feedback.
8) **Security Vulnerability Prediction and Prevention:** Enhance AI models to predict and prevent potential security vulnerabilities by analyzing code patterns and emerging threats.

VII. APPENDICES

The appendix includes supplementary materials such as the folder structure of the AIRA project, screenshots demonstrating key functionalities, and detailed explanations of the algorithms used in the system.

A. *Appendix A: Folder Structure*

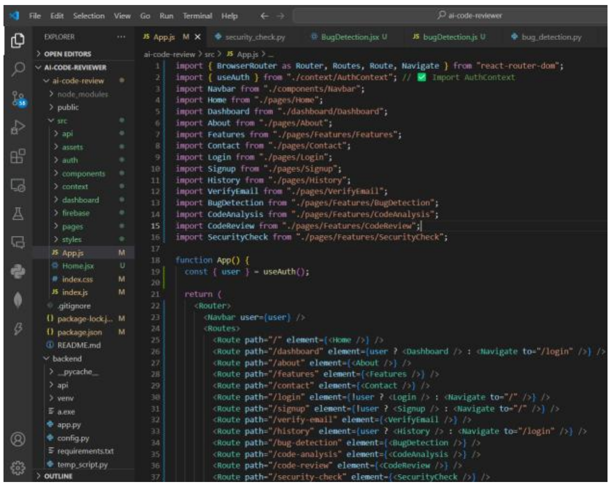

```
import { BrowserRouter as Router, Routes, Route, Navigate } from "react-router-dom";
import { useAuth } from "./context/AuthContext"; // ✅ Import AuthContext
import Navbar from "./components/Navbar";
import Home from "./pages/Home";
import Dashboard from "./dashboard/Dashboard";
import About from "./pages/About";
import Features from "./pages/Features/Features";
import Contact from "./pages/Contact";
import Login from "./pages/Login";
import Signup from "./pages/Signup";
import History from "./pages/History";
import VerifyEmail from "./pages/VerifyEmail";
import BugDetection from "./pages/Features/BugDetection";
import CodeAnalysis from "./pages/Features/CodeAnalysis";
import CodeReview from "./pages/Features/CodeReview";
import SecurityCheck from "./pages/Features/SecurityCheck";

function App() {
  const { user } = useAuth();

  return (
    <Router>
      <Navbar user={user} />
      <Routes>
        <Route path="/" element={<Home />} />
        <Route path="/dashboard" element={user ? <Dashboard /> : <Navigate to="/login" />} />
        <Route path="/about" element={<About />} />
        <Route path="/features" element={<Features />} />
        <Route path="/contact" element={<Contact />} />
        <Route path="/login" element={!user ? <Login /> : <Navigate to="/" />} />
        <Route path="/signup" element={!user ? <Signup /> : <Navigate to="/" />} />
        <Route path="/verify-email" element={<VerifyEmail />} />
        <Route path="/history" element={user ? <History /> : <Navigate to="/login" />} />
        <Route path="/bug-detection" element={<BugDetection />} />
        <Route path="/code-analysis" element={<CodeAnalysis />} />
        <Route path="/code-review" element={<CodeReview />} />
        <Route path="/security-check" element={<SecurityCheck />} />
```

Fig. 7. AIRA: Folder Structure

B. *Appendix B: Detailed Algorithm Explanation*

1) Bug Detection and Code Analysis Algorithm: The bug detection and code analysis algorithm leverages AI models and tools like `Pylint`, `SonarQube`, and `Bandit` to identify bugs, code smells, and security vulnerabilities. The process follows these steps:

- **Code Input:** User uploads the source code for analysis.
- **Preprocessing:** Code is cleaned and formatted for consistency.
- **AI-Based Analysis:** The AI model scans the code for issues and vulnerabilities.
- **Pattern Recognition:** Predefined patterns and anomalies are detected.
- **Result Compilation:** A detailed report is generated with issues and suggestions.

2) Security Vulnerability Scanner: The security scanner is based on `Bandit` and custom AI models. It evaluates the code for potential security threats and generates a security report. The process includes:

- **Input Processing:** Code is analyzed for common security flaws.
- **Threat Identification:** AI models flag potential vulnerabilities.
- **Severity Analysis:** Detected issues are classified based on severity.
- **Recommendation Generation:** Suggestions for resolving vulnerabilities are provided.

3) Code Refactoring and Optimization Algorithm: The refactoring algorithm uses machine learning techniques to optimize code structure and improve performance. The process follows:

- **Structural Analysis:** Code is scanned for inefficiencies and redundant patterns.
- **Pattern Matching:** The AI model identifies and suggests alternative approaches.
- **Performance Testing:** Proposed changes are evaluated for performance gains.
- **Refactoring Suggestions:** Users are provided with optimized code suggestions.

C. Appendix C: Screenshots of Functionalities

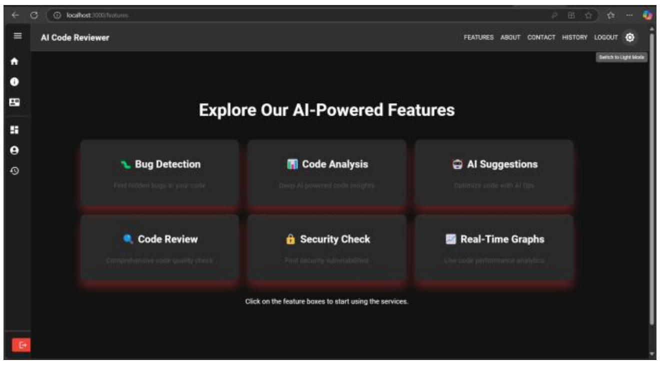
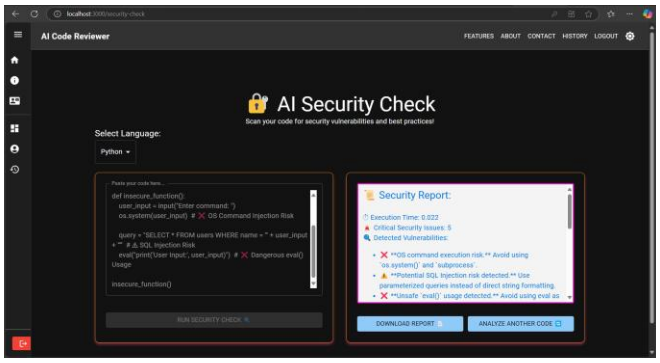

localhost:3000/features
AI Code Reviewer
FEATURES ABOUT CONTACT HISTORY LOGOUT
Switch to Light Mode
Explore Our AI-Powered Features
Bug Detection
Find hidden bugs in your code
Code Analysis
Deep AI-powered code insights
AI Suggestions
Optimize code with AI tips
Code Review
Comprehensive code quality check
Security Check
Find security vulnerabilities
Real-Time Graphs
Live code performance analytics
Click on the feature boxes to start using the services.

Fig. 8. AIRA: Feature Page



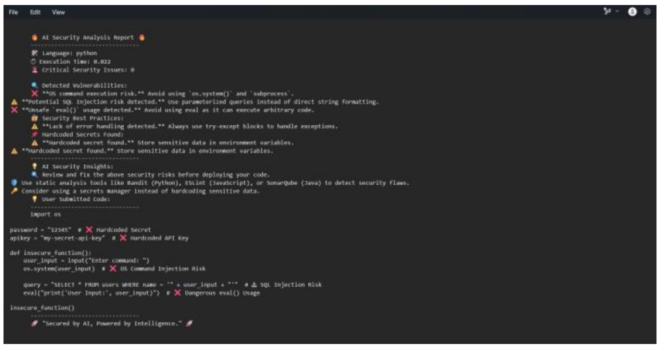
```
def insecure_function():
   user_input = input("Enter command: ")
   os.system(user_input) # ❌ OS Command Injection Risk

   query = "SELECT * FROM users WHERE name = '" + user_input
+ "'" # ⚠ SQL Injection Risk
   eval("print('User Input:', user_input)") # ❌ Dangerous eval()
Usage

insecure_function()
```

Security Report:

⏱ Execution Time: 0.022
🔺 Critical Security Issues: 5
🔍 Detected Vulnerabilities:

- ❌ **OS command execution risk.** Avoid using `os.system()` and `subprocess`.
- ⚠ **Potential SQL Injection risk detected.** Use parameterized queries instead of direct string formatting.
- ❌ **Unsafe `eval()` usage detected.** Avoid using eval as

Fig. 9. AIRA: AI Security Check



```
      🔴 AI Security Analysis Report 🔴
      --------------------------------
      🛠 Language: python
      ⏱ Execution Time: 0.022
      🚨 Critical Security Issues: 0

      🔍 Detected Vulnerabilities:
      ❌ **OS command execution risk.** Avoid using `os.system()` and `subprocess`.
⚠ **Potential SQL Injection risk detected.** Use parameterized queries instead of direct string formatting.
❌ **Unsafe `eval()` usage detected.** Avoid using eval as it can execute arbitrary code.
      🎁 Security Best Practices:
      ⚠ **Lack of error handling detected.** Always use try-except blocks to handle exceptions.
      📌 Hardcoded Secrets Found:
      ⚠ **Hardcoded secret found.** Store sensitive data in environment variables.
⚠ **Hardcoded secret found.** Store sensitive data in environment variables.
      --------------------------------
      💡 AI Security Insights:
      🔍 Review and fix the above security risks before deploying your code.
🛡 Use static analysis tools like Bandit (Python), ESLint (JavaScript), or SonarQube (Java) to detect security flaws.
🔑 Consider using a secrets manager instead of hardcoding sensitive data.
      💡 User Submitted Code:
      --------------------------------
      import os

password = "12345"  # ❌ Hardcoded Secret
apikey = "my-secret-api-key"  # ❌ Hardcoded API Key

def insecure_function():
    user_input = input("Enter command: ")
    os.system(user_input)  # ❌ OS Command Injection Risk

    query = "SELECT * FROM users WHERE name = '" + user_input + "'"  # ⚠ SQL Injection Risk
    eval("print('User Input:', user_input)")  # ❌ Dangerous eval() Usage

insecure_function()
      --------------------------------
      🚀 "Secured by AI, Powered by Intelligence." 🚀
```

Fig. 10. AIRA: Code Analysis Report

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