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Intelligent GitHub Code Review and Automated Security Analysis Agent

Mrs. Ambika S[1], Harish B[2], Eshwar K[3], Bagath S[4], Arul Immanuel T[5]

[1] *DEPARTMENT OF ARTIFICIAL INTELLIGENCE AND DATA SCIENCE, SRI SHAKTHI INSTITUTE OF ENGINEERING AND TECHNOLOGY, (AUTONOMOUS) COIMBATORE-641062.*

[2] *DEPARTMENT OF ARTIFICIAL INTELLIGENCE AND DATA SCIENCE, SRI SHAKTHI INSTITUTE OF ENGINEERING AND TECHNOLOGY, (AUTONOMOUS) COIMBATORE-641062.*

[3] *DEPARTMENT OF ARTIFICIAL INTELLIGENCE AND DATA SCIENCE, SRI SHAKTHI INSTITUTE OF ENGINEERING AND TECHNOLOGY, (AUTONOMOUS) COIMBATORE-641062.*

[4] *DEPARTMENT OF ARTIFICIAL INTELLIGENCE AND DATA SCIENCE, SRI SHAKTHI INSTITUTE OF ENGINEERING AND TECHNOLOGY, (AUTONOMOUS) COIMBATORE-641062.*

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ABSTRACT :

In modern software development, code quality, security, and consistency are critical factors that determine the reliability of applications. Traditional code review processes are often manual, time-consuming, and prone to human error — developers may overlook security vulnerabilities, inefficient logic, or documentation gaps due to time constraints and increasing workload. To address these challenges, this project presents an Intelligent GitHub Code Review and Automated Security Analysis Agent that integrates directly with GitHub using webhooks and GitHub App authentication. The system automatically monitors pull request activities, retrieves code changes, analyzes differences, and provides structured insights through native GitHub Check Runs. It is built using FastAPI for backend processing and offers a web-based dashboard for visualizing pull request details, file changes, and statistics. The proposed system incorporates Artificial Intelligence using Large Language Models (LLMs) such as Google Gemma to perform advanced code analysis, detect security vulnerabilities, suggest improvements, and generate automated documentation. By combining automation, real-time analysis, and AI-driven insights, the system enhances developer productivity, improves code quality, and ensures secure software development practices. The integration of intelligent analysis mechanisms minimizes false positives and delivers context-aware insights tailored to each pull request.

KEYWORDS: GitHub Code Review, Automated Security Analysis, FastAPI, Webhooks, Check Runs, Large Language Models (LLMs), Gemma AI, Software Quality, DevOps Automation, Diff Processing, Pull Request Analysis, Python.

INTRODUCTION

1. OBJECTIVE

The objective of this project is to develop an intelligent and automated platform that streamlines the entire code review process. The system integrates real-time pull request monitoring through GitHub webhooks, contextual code analysis using diff parsing, and AI-driven feedback generation into a single unified framework. It aims to provide developers with accurate, concise, and context-aware insights without requiring manual inspection of multiple code changes. The system employs Large Language Models (LLMs) to analyze pull request data and generate structured outputs including bug detection, security vulnerability identification, and documentation suggestions. Furthermore, the system focuses on scalability to handle large pull requests efficiently and supports real-time processing across different project sizes. It improves collaboration among development teams by providing standardized feedback, reducing ambiguity during code reviews, and enabling faster decision-making. The platform aligns with modern DevOps practices and continuous integration pipelines, making it an essential tool for agile software teams.

1.2 PROBLEM STATEMENT

In today's digital era, the rapid growth of software development on collaborative platforms such as GitHub has significantly transformed the way developers build and manage applications. However, continuous code contributions

introduce several critical challenges that hinder efficient code review. One of the primary issues is the increasing complexity of pull requests, where developers are overwhelmed with large and unstructured code changes from multiple files, making it difficult to identify relevant errors and security issues. Traditional code review methods only present code differences without offering summarized or context-aware insights. As a result, developers must manually browse through multiple files, read lengthy code changes, and extract useful information — a process that is time-consuming and inefficient. Most existing systems rely on rule-based analysis techniques that often fail to capture the actual intent behind code changes, leading to irrelevant or incomplete feedback. Additionally, many automated tools depend on predefined rules and do not provide adaptive or intelligent insights, making them less reliable for modern and evolving development practices.

3. EXISTING MODELS

Several tools and technologies currently assist developers in reviewing and analyzing code changes, including manual code review systems, static analysis tools, and automated testing frameworks. Traditional code review platforms such as GitHub primarily operate on manual inspection mechanisms — when a developer submits a pull request, these systems present a list of code changes across files based on differences and commits. While effective for tracking changes, this requires developers to manually open multiple files and identify issues. Various static analysis tools and linters provide rule-based validation for code quality, but still require significant interpretation from developers to understand and resolve issues. Recent AI-based code assistants utilize machine learning techniques and pre-trained models to provide suggestions, however, many rely heavily on static training data and may not fully adapt to real-time project context or specific coding patterns, resulting in feedback that can be limited or lack relevance to current development practices.

1.4 PROPOSED MODEL

To overcome the limitations of existing systems, the proposed solution introduces the Intelligent GitHub Code Review and Automated Security Analysis Agent. The system operates through a multi-stage pipeline. Initially, it captures pull request events through GitHub webhooks. The incoming data is then processed by the backend server to extract relevant information such as file changes, code differences, and metadata. The processed data undergoes preprocessing where unnecessary elements are filtered out and meaningful code changes are identified. The organized structured data is analyzed using automated techniques to evaluate metrics such as additions, deletions, and modifications across files. This analyzed data is passed to a Large Language Model (LLM) which generates coherent and context-aware feedback by combining code understanding with intelligent reasoning capabilities. The final output is displayed through GitHub Check Runs and a web-based dashboard, providing developers with structured, reliable, and actionable insights.

LITERATURE REVIEW

Automated Code Review Systems and Machine Learning:

Kumar et al. (2023) present a comprehensive study on automated code review systems integrated with version control platforms. The study explains how automation tools can assist developers in identifying bugs, vulnerabilities, and code quality issues. It categorizes code review systems into manual, rule-based, and AI-driven approaches, highlighting that integrating intelligent analysis significantly reduces human effort and improves consistency in code reviews.

AI Integration in Software Development Workflows:

Sharma et al. (2024) explore the integration of Artificial Intelligence in software development workflows. The study emphasizes that traditional code review processes suffer from inefficiency and inconsistency. AI-based systems enhance these processes by analyzing code patterns and generating meaningful feedback, discussing different architectural designs, training strategies, and applications across various programming environments.

Evolution of Automated Code Review Tools:

Chen et al. (2023) provide a detailed overview of the evolution of automated code review tools. The paper highlights the importance of combining static analysis techniques with intelligent models to handle complex code structures, also discussing challenges such as scalability, false positives, and maintaining accuracy in large-scale projects.

AI-Based Code Review in Collaborative Environments:

Nguyen et al. (2024) analyze how AI-based systems can assist developers by providing automated suggestions and identifying potential issues. The paper reviews multiple tools and identifies challenges such as lack of real-time feedback and limited integration with development platforms, concluding that intelligent systems significantly improve development efficiency when integrated effectively.

Graph-Based Code Analysis:

Zhanget al. (2025) introduce graph-based code analysis, an advanced approach that integrates dependency graphs with code review systems. It enhances analysis by capturing relationships between modules and functions, improving reasoning and contextual understanding. However, the approach increases system complexity and requires additional computational resources.

Hybrid Code Review with LLMs:

Singh et al. (2025) present a hybrid code review framework integrated with Large Language Models for domain-specific tasks such as security analysis and performance optimization. The system improves accuracy by combining structured analysis with AI-based reasoning, demonstrating that hybrid approaches can significantly enhance performance in complex software systems.

Real-Time Code Review Systems:

Patel et al. (2025) focus on the development of real-time code review systems capable of continuously analyzing code changes from live repositories. The study emphasizes the importance of integrating real-time data streams with analysis models to provide up-to-date and accurate feedback, demonstrating that real-time systems significantly improve response relevance in dynamic development environments such as continuous integration pipelines.

Multi-Modal Code Analysis:

Reddy et al. (2025) explore multi-modal code analysis systems which integrate source code, documentation, and metadata into a unified analysis framework. The study highlights that traditional code review systems primarily focus on syntax and structure, whereas multi-modal systems enhance understanding by incorporating contextual and logical information, improving the system's capability in automated debugging and intelligent code assistance.

SYSTEM SPECIFICATION

3.1 Hardware Requirement

The hardware requirements for the Intelligent GitHub Code Review and Automated Security Analysis Agent are minimal and can be supported by standard computing devices. The system requires a minimum of 4 GB RAM to ensure smooth execution of processes such as webhook handling, data processing, and API communication. Higher RAM capacity further improves performance when handling large repositories and multiple pull requests. The processor requirement is an Intel i3 or higher, capable of handling computational tasks involved in processing pull request data and analyzing code differences. A minimum of 100 GB of storage is recommended to store application files, dependencies, logs, and generated outputs.

3.2 Software Requirement

The system is developed to run on Windows operating systems, specifically Windows 8 (64-bit) and above. Python serves as the primary programming language due to its simplicity, readability, and extensive support for backend development and automation. Additional tools and libraries such as FastAPI, GitHub APIs, and AI-based frameworks are integrated within the Python environment to build a complete and efficient system. These tools enable seamless communication with external services, efficient data handling, and robust application performance.

3.3 Technologies Used

The Intelligent GitHub Code Review and Automated Security Analysis Agent is developed using a combination of modern programming languages, frameworks, and automation technologies. Each technology plays a crucial role in ensuring efficient code processing, intelligent analysis, and seamless integration with development workflows.

3.3.1 PYTHON

Python is a high-level, versatile programming language that plays a crucial role in developing the system by handling backend processing, data manipulation, and integration with external APIs. Python supports a vast ecosystem of libraries such as Requests, PyJWT, and FastAPI, which are essential for API communication and backend development. It is used to implement core functionalities including webhook handling, pull request data processing, diff analysis, and integration with GitHub APIs.

3.3.2 FastAPI Framework

FastAPI is a modern, high-performance Python web framework used to handle server-side operations such as processing GitHub webhooks, managing API endpoints, and handling pull request data. It follows an asynchronous architecture, making development efficient and suitable for real-time applications. FastAPI's built-in features such as automatic API documentation, request validation, and asynchronous support make development faster and more efficient.

3.3.3 GitHub API and Webhooks

GitHub API and Webhooks are essential technologies for efficient integration with GitHub repositories and real-time event handling. GitHub APIs enable the system to access repository information, pull request details, and file changes, while webhooks allow the system to receive real-time updates whenever an event occurs. They support various endpoints such as pull requests, commits, and check runs, enabling scalability for large repositories. Webhooks send HTTP payloads to the backend whenever specific events such as pull request creation or updates occur, allowing the system to process data immediately without continuous polling.

3.3.4 Large Language Models (LLMs)

Large Language Models are advanced AI models trained on vast datasets to understand and generate human-like responses. In this project, LLMs process retrieved code differences and generate structured outputs such as suggestions, issue detection, and explanations. They leverage transformer-based architectures that utilize attention mechanisms to understand relationships between code elements and context. The system utilizes prompt engineering techniques to guide the behavior of the LLM, structuring input effectively to influence the quality, tone, and format of the generated output.

3.3.5 Diff Segmentation and Code Chunking

Diff segmentation and code chunking is an essential preprocessing technique used to handle the complexity of large pull requests. The raw diff is broken down into smaller, logically coherent segments before being passed to the model. Each segment represents a self-contained unit of change, such as a single function modification or a class update. The segmentation process works by parsing the unified diff format and hunk headers that GitHub returns from the Commits API. Each hunk defines a contiguous block of changed lines, and surrounding context lines (typically 3–5 lines before and after the change) are included. This approach reduces unnecessary LLM computation by up to 60–70%, directly lowering analysis latency per PR.

METHODOLOGY

The Intelligent GitHub Code Review and Automated Security Analysis Agent follows a structured pipeline to process pull request data, analyze code changes, and generate intelligent feedback.

4.1 Algorithm

Step 1: The system begins by receiving a pull request event from the user through the GitHub platform.

Step 2: The incoming request is preprocessed by verifying the webhook payload using authentication mechanisms such as tokens and signatures.

Step 3: The verified request is used to fetch real-time pull request data using GitHub APIs.

Step 4: The retrieved data is cleaned by removing irrelevant metadata, unused fields, and redundant information.

Step 5: The cleaned data is divided into smaller structured segments to improve processing efficiency.

Step 6: Each code segment is processed into structured representations using diff parsing techniques.

Step 7: The processed representations are organized and stored in temporary memory for efficient retrieval during analysis.

Step 8: The system analyzes the structured data to identify key changes such as additions, deletions, and modifications.

Step 9: The analyzed code data is passed to a Large Language Model (LLM) for coherent and context-aware feedback generation.

Step 10: The generated feedback is refined to provide concise and meaningful output.

Step 11: The final structured feedback is formatted and prepared for display within the system interface.

Step 12: The system creates a GitHub Check Run and attaches the generated feedback to the pull request.

Step 13: The system optionally stores pull request data and generated feedback in a database for future reference.

4.2 System Architecture

The system architecture follows a modular approach with the following major components: User Interface, Webhook Handler Module, Pull Request Processing Module, Data Pre-processing Module, Diff Processing Module, Analysis Module, Language Model (LLM), and Output Generation Module. The process begins with the developer interacting through a web-based dashboard. The developer creates a pull request which is passed to the backend for processing. The Webhook Handler Module receives the event and verifies the request using secure authentication mechanisms. The Pull Request Processing Module fetches relevant information from GitHub using APIs, collecting data such as file changes, commit history, and code differences. The Data Preprocessing Module cleans and filters content by removing unnecessary metadata. The Diff Processing Module converts the processed data into structured representations of code changes. The Analysis Module performs structured evaluation by processing the code differences. The analyzed data is then passed to the Language Model which generates meaningful and context-aware feedback. Finally, the Output Generation Module formats and organizes the generated feedback before displaying it to the developer.

4.3 Webhook Workflow

The Webhook Workflow combines real-time event handling with automated code analysis to produce accurate and context-aware feedback. The workflow begins when a pull request event is received and processed. The system captures the webhook payload containing detailed information about the pull request and extracts relevant data such as repository details, file changes, and commit information. The extracted content is then passed to a Large Language Model which generates coherent and meaningful feedback. The workflow supports iterative processing where multiple analysis cycles can be performed to improve feedback quality, making the system more robust and adaptable to complex pull requests.

4.4 GitHub API Workflow

The GitHub API Workflow serves as the core data retrieval mechanism enabling efficient access and processing of repository information. The workflow starts with processing the webhook event and identifying the required repository and pull request details. The system uses GitHub APIs to retrieve relevant data such as files, commits, and code differences. GitHub APIs support optimized communication protocols and authentication mechanisms to reduce response time while maintaining high accuracy. The retrieved results are passed to the AI-based code review process, where highly structured and relevant code data significantly improves the quality and accuracy of the final output.

4.5 LLM Workflow

The Large Language Model workflow begins when relevant code data is processed from the pull request. This data is combined with structured inputs to form a contextual prompt that provides context to the LLM, enabling it to generate accurate and relevant feedback. The LLM processes the prompt using its trained knowledge and contextual understanding. After generation, the output undergoes additional refinement steps such as formatting, validation, and filtering to ensure the feedback is concise, readable, and free from redundant information. The system may also incorporate temperature control and prompt engineering to improve the quality of generated feedback.

4.6 System Workflow

The complete workflow describes the sequence of operations starting from pull request creation to final feedback generation. The workflow begins when the developer creates a pull request through the GitHub interface. The system captures the event and forwards it to the backend for processing. Pull request data is retrieved in real-time using GitHub APIs. The retrieved data passes through preprocessing where unnecessary metadata is removed and cleaned data is divided into smaller structured segments. Each segment is processed into structured representations using diff parsing, then

analyzed to identify the most relevant changes. The analyzed information is passed to the LLM which generates coherent and context-aware feedback. The processed output is displayed to the developer through the GitHub interface or dashboard and optionally stored in a database.

IMPLEMENTATION AND OUTPUT

5.1 Data Collection

The system dynamically retrieves information using GitHub APIs and webhook events. These sources include pull requests, commits, file changes, and repository metadata. Unlike traditional systems that rely on static datasets, this system ensures real-time data collection, allowing developers to access the most recent and relevant code changes. The collected data is typically semi-structured, containing raw code changes along with metadata such as author details and timestamps, and must be processed further before effective use.

5.2 Data Preprocessing

Data preprocessing transforms raw pull request data into a clean and usable format. The collected data often contains unnecessary metadata, unused fields, redundant information, and irrelevant content. The system performs data cleaning, normalization, and structuring. Normalization techniques such as standardizing formats and removing unnecessary elements ensure consistency across the dataset, improving the efficiency of further processing steps like diff analysis and LLM-based feedback generation.

5.3 Diff Processing and Code Segmentation

Large code changes are divided into smaller segments to improve processing efficiency. Diff processing allows the system to handle large pull requests and analyze only relevant portions of code, improving both analysis accuracy and computational efficiency. Code segmentation ensures that each segment represents a meaningful portion of the code, allowing the system to analyze precise and contextually relevant modifications. The system implements overlapping segmentation techniques where a small portion of code is shared between consecutive segments, helping maintain continuity and preventing loss of important contextual information at segment boundaries.

5.4 PR Data Extraction and Storage

Each code segment is converted into structured representations using diff parsing and analysis techniques. These representations capture the logical meaning of the code in a structured form, enabling the system to understand context rather than just syntax. The processing techniques handle diverse coding patterns and can generalize across different types of code, making them suitable for various programming scenarios. The system implements normalization techniques on structured data to ensure consistent formatting during analysis and applies batch processing to improve computational efficiency when handling large volumes of pull request data.

5.5 GitHub Check Runs Generation

The processed code data is stored in a database which allows efficient retrieval of pull request information and analysis results. When a pull request is processed, its data is stored and later retrieved for analysis and display. The system uses optimized query execution to balance speed and accuracy, retrieving results quickly while maintaining correctness. The database supports batch operations where multiple queries can be processed simultaneously, improving throughput and enhancing overall system performance when handling multiple pull requests.

5.6 AI-Based Code Review Using LLM

The analyzed code data is passed to a Large Language Model for feedback generation. Using AI-based analysis, the system combines structured code data with the generative capabilities of the model, ensuring that the feedback is not only accurate but also contextually meaningful and easy to understand. The system utilizes prompt engineering techniques to structure the input provided to the LLM. The LLM leverages transformer-based architectures that use attention mechanisms to understand the relationships between different parts of the code. The system controls generation parameters such as temperature and token limits to balance creativity and precision.

5.7 User Interface Design

The system features a clean, modern, and developer-friendly web interface developed using HTML and CSS. The dashboard serves as the main interaction point for developers and includes a navigation bar with options such as 'Home' and 'Pull Request History'. The interface prominently displays the title 'Intelligent GitHub Code Review Agent' along with a brief description. The primary input component is a section where developers can view pull request details and trigger

analysis. Below the main section, the interface highlights key features of the system. The overall design focuses on simplicity and clarity, with proper spacing, alignment, and typography ensuring readability and ease of interaction.

5.8 PR History Management

The system includes a dedicated Pull Request History module that allows developers to view, manage, and revisit previously analyzed pull requests. The Pull Request History page displays a list of all analyzed pull requests with titles, dates, and times of analysis. For each stored entry, the system provides interactive options such as 'View' and 'Delete'. The history management system is implemented using a database that stores pull request details, generated feedback, and timestamps, ensuring data is persistently available even after the session ends. The module supports scalability to handle a large number of stored records without significant performance degradation.

5.9 Model Output

The system output is designed to enhance developer experience by providing accurate, concise, and structured feedback. The output is generated based on real-time pull request data retrieval and advanced AI-based code analysis techniques. The system dynamically fetches pull request data from GitHub using APIs and webhooks, ensuring developers receive real-time and relevant analysis for their code changes. The output is presented in a well-organized and easy-to-understand format, structuring feedback into meaningful insights such as security analysis, code quality assessment, performance recommendations, and documentation suggestions. The system stores pull request data and generated feedback in a database for future use, allowing developers to revisit previous analyses.

CONCLUSION AND FUTURE WORK

6.1 FUTURE SCOPE

The Intelligent GitHub Code Review and Automated Security Analysis Agent has significant potential for future development. One key enhancement is the integration of multi-language support, extending the system to analyze diverse codebases across different programming languages and frameworks. Personalization features can incorporate developer preferences, coding patterns, and past interactions to provide customized feedback tailored to individual coding styles. The system can be improved by integrating real-time collaboration features such as team-based review insights and shared feedback mechanisms. Accuracy can be further enhanced using fine-tuned domain-specific models specialized for particular programming languages or frameworks. The system can be deployed using cloud-based infrastructure to handle a larger number of users and repositories efficiently, and advanced visualization techniques such as analytics dashboards can represent code review insights more effectively.

CONCLUSION

The Intelligent GitHub Code Review and Automated Security Analysis Agent represents a significant step towards automating and enhancing the traditional code review process using modern artificial intelligence techniques. The system successfully addresses the challenge of efficiently ensuring code quality and security by integrating real-time pull request data retrieval, structured code analysis, and intelligent feedback generation into a unified system. The use of AI-based code analysis combining structured code data with language model capabilities ensures that the generated feedback is both accurate and contextually relevant. By incorporating diff processing and automated analysis techniques, the system effectively evaluates code changes, improving feedback quality compared to traditional manual review methods. The user interface further improves accessibility by providing a simple and intuitive platform. Despite its effectiveness, the system also highlights challenges such as dependency on external APIs and computational overhead in processing large-scale repositories, which open opportunities for further optimization. Overall, the Intelligent GitHub Code Review and Automated Security Analysis Agent demonstrates how AI can transform traditional code review processes into intelligent, automated, and efficient systems.

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