Addendum

THE UNIVERSITY OF DANANG
DANANG UNIVERSITY OF SCIENCE AND TECHNOLOGY
FACULTY OF INFORMATION TECHNOLOGY

GRADUATION PROJECT THESIS

MAJOR: INFORMATION TECHNOLOGY

SPECIALTY: SOFTWARE ENGINEERING

PROJECT TITLE:

MYGRATE: AI AGENT SOLUTION FOR MIGRATING CODEBASES

Instructor: **DR. NINH KHÁNH DUY**
Student: **TRẦN THANH TÙNG**
Student ID: **102210138**
Class**:** **21T_DT2**

Da Nang, 06/2026

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SUMMARY

Topic title: Mygrate: AI Agent Solution for Migrating Codebases

Student name: Trần Thanh Tùng

Student ID: 102210138 Class: 21T_DT2

Upgrading legacy software is always a big challenge in software development, especially when the system contains many dependencies in its own source code (dependency hell) and the API changes in the language or framework itself. This Capstone Project focuses on addressing this problem by an idea of applying Multi-Agent System to translate codebase from the previous version to the target one. The final goal of this project is to provide a Proof-of-Concept project of trying a new approach on a verified Java dataset.

Observing that there are some solutions in the community but still, they are mostly LLM based on their knowledge of software engineering to translate code. Mygrate tackles this problem by applying hybrid approach, combine reasoning ability of LLM and static analysis. With the help of tools like jdeprscan from Oracle to scan bytecode so that depreciated APIs could be highlighted, ready to translate.

The core architecture comes with different agents for different tasks. The experiment results show Mygrate has the ability to apply such a simple method and a new base to develop robust solutions in the future – this is the core of this project.

During the process doing this Capstone Project, I have received cares, and helpful guides from friends, families and professors. First, I want to gratefully thank professor **Dr. Ninh Khanh Duy**. Dr. Duy has directly guides me, has shown different guides and approaches through constructive advices to overcome engineering deadlocks to make this Capstone Project finished on time. Moreover, special thanks to the Board of Rectors of the University of Science and Technology - The University of Da Nang, along with all the professors and lecturers of the Faculty of Information Technology for providing the best learning conditions and imparting to me a solid foundation in software engineering and artificial intelligence throughout the years.

Đà Nẵng, date 18 month 06 year 2026

Student Performed

Trần Thanh Tùng

DA NANG UNIVERSITY
UNIVERSITY OF SCIENCE AND TECHNOLOGY
FACULTY OF INFORMATION TECHNOLOGY

THE SOCIALIST REPUBLIC OF VIETNAM
Independence - Freedom - Happiness

GRADUATION PROJECT REQUIREMENTS

Student Name: Trần Thanh Tùng Student ID: 102210138

Class: 21T_DT2 Faculty: Information Technology Major: Software Engineering

1. *Topic title:*

Mygrate: AI Agent Solution for Migrating Codebases

2. *Project topic :* ☐ *has signed intellectual property agreement for final result*
3. *Initial figure and data:*

Containing the usage of FreshBrew dataset, published by Google

Content of the explanations and calculations:

- Section 1: Introduction
- Section 2: Theoretical basis
- Section 3: Implementation Results
- Section 4: Conclusion and Future Works
- Conclusion: Summary of the project, achieved results, limitations and development directions in the future

4. *Drawings, charts (specify the types and sizes of drawings):*
   - Behavior diagrams
   - Evaluation plots

5. *Name of instructor:*	*Content parts:*

6. *Date of assignment : 06/03/2026*
7. *Date of completion : 18/03/2026*

Đà Nẵng, date 01 month 7 year 2026

Head of Division……. **Instructor**

PREFACE

Topic title: Mygrate: AI Agent Solution for Migrating Codebases

Student name: Trần Thanh Tùng

Student ID: 102210138 Class: 21T_DT2

In the world these days, with the fast pace of software development, technical debt is an always a problem that development teams have to face repetitively. Observing this problem and the AI LLM trend is developing, I come up with an idea to applying AI agents to solve the problem of migrating codebases as “Mygrate: AI Agent Solution for Migrating Codebases”

The research and development of this project has gone through the following checkpoints:

1. **Idea Refinement:** Researching the way industry normally does if no LLM applied, and drawing out pain points to tackle
2. **Solution Designing:** Researching from available papers to inherit their approaches and dataset to find a benchmark to base on.
3. **Development:** Building the core architecture, setting up the workflow.
4. **Testing and Benchmarking:** Testing on the chosen dataset, and feedback loop to improve the benchmarks.

The result of this Capstone project is a solution stands as a Proof-of-Concept with benchmark on a verified dataset. This Capstone Project not just providing a case-study to applying AI/LLM skills but also a contribution to the available solution to the community of developers, later to base on and develop better tweaks.

ASSURANCE

I assure:

5. The content of this project was carried out by me under the direct supervision of Dr. Ninh Khanh Duy
6. All references used in this thesis/project are properly cited, including the author(s), title of the work, publication date, publication venue, and valid source links where applicable.
7. If any unauthorized copying or violations of academic regulations are found, I shall bear full responsibility for them.

Da Nang, date 01 month 7 year 2026

Student Performed

Trần Thanh Tùng

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LIST OF ACRONYMS

Acronym	Meaning
JDK	Java Development Kit
LLM	Large Language Model
AST	Abstract Syntax Tree
AI	Artificial Intelligence
JAR	Java Archive

INTRODUCTION

1. Purpose of the Study

Migrating legacy software systems often involves high risks related to technical debts and dependency hell. Manually upgrades are time-consuming and expensive. Meanwhile, traditional rule-based tools lack the flexibility to handle complex logic, and standalone Large Language Models (LLMs) are prone to "hallucinations" that can break the overall code structure or using non-existed snippets. Therefore, there is an urgent need to research a hybrid solution – the one that combines the contextual reasoning of AI with the accuracy of structural code analysis – as a proposed method for the migration process.

2. Research Objectives

This project aims to design and develop Mygrate, an autonomous AI Agent solution specialized for automated codebase migration. The specific objectives includes:

- Implementing a Mulit-Agent System (MAS) using ReAct framework, enabling the AI to autonomously analyze errors, plan, and coordinate code fixes.
- Building an end-to-end automated pipeline: from detecting compilation errors and generating patches to running test suites, and checking if the Reward Hacking is occurred
- Evaluate the results: evaluating results through metrics, and present some patterns that make the pipeline to fail.

3. Research Scope and Subjects

- Research Subjects: The study focuses on Large Language Model (LLM) architectures, Autonomous Agent systems, static code analysis, and automated compilation/testing workflows.
- Research Scope: The project is strictly focused on codebase migration and library upgrades within Java projects. The proposed solution is deployed and empirically evaluated on Google's FreshBrew benchmark dataset.

4. Research Methodology

- Theoretical Research: Reviewing scientific literature and technical documentation regarding the Transformer architecture, the ReAct framework, JSON data structures in AST processing, and current codebase migration solutions in Java, as well as Java related project management system.
- Empirical Research (System Development):
  + Building a multi-agent workflow that integrates with file systems and compiler tools.
  + Programming an AST retrieval tool that forces the LLM to generate modifications in a structured JSON format instead of free-form text.
  + Deploying the solution in an isolated environment to test it on real-world Java repositories from the FreshBrew dataset.
  + Collecting and analyzing data on the compilation success rate and test execution status to refine the system.

5. Thesis Structure

This Capstone Project's thesis is organized into the following main sections:

- **Introduction:**
- **Chapter 1: Theoretical Basis** – introduces the context of technical debts, static detection tools, Agents with ReAct, and the FreshBrew dataset.
- **Chapter 2: Proposed Solution** – presents the proposed method, from the overall architecture, to the specified architectures for each agent.
- **Chapter 3: Implementation Results** – this chapter brings the results by metrics to compare with preexisted solutions, as well as some findings about how and why it fails.
- **Chapter 4: Conclusion and Future Works** – wrapping up, and some ways to improve this method.

CHAPTER 1: THEORETICAL BASIS

This chapter establishes the foundational concepts required for developing an autonomous AI Agent solution for migrating codebases. Beginning by examining the challenges of technical debt within the Java ecosystem, a glance of related existed solution for this problem. Then followed by the overview of static code analysis techniques used to parse and modify code structures. Subsequently, it explores the architecture of Large Language Models and Multi-Agent Systems, focusing on the ReAct framework. Finally, it introduces the benchmark dataset utilized to evaluate the effectiveness of the migration process.

1.1. The Codebase Migration Challenges

Migrating legacy software is not merely a task of syntax translation; it is a complex process of resolving accumulated structural inefficiencies. This section explores the primary obstacles encountered during Java codebase migrations, specifically focusing on technical debt and platform-level deprecations.

1.1.1. Technical Debts and Migrating Codebases

Technical Debt [1], first defined by W. Cunningham in 1992, is a hidden cost of additional rework caused by choosing an easy, limited solution instead of a better approach. In legacy software systems, this dept accumulates through time as outdated libraries, unmaintained codebases and security. The biggest challenge is the "Dependency Hell" effect, with Transitive Dependencies when many libraries depend on other libraries which causes version conflicts. Upgrading a core library in this case can cause numerous child libraires to break due to incompatibility.

1.1.2. Java Platform Evolution and Static Detection

The Java ecosystem has undergone core architectural changes from Java 8 to Java 17. Through the time, many updates have changed API, which resulted in a lot of them marked as `@Deprecated`, or even removed.

To help developers from this problem, Oracle introduced jdeprscan as a static analysis tool specifically designed to scan compiled class files and JAR assemblies for Cross Bytecode Version Analyze. Unlike standard compiler warnings that only trigger during source code compilation, jdeprscan operates directly on bytecode. By parsing the constant pool of compiled files, it maps referenced classes, methods, and fields against a predefined list of deprecated APIs for a target Java release. This distinction is highly valuable for migration processes, as it allows developers to identify legacy dependencies

or third-party libraries that rely on outdated or removed Java APIs without requiring access to their original source code.

However, while static detection tools like jdeprscan excel at highlighting where the deprecations exist, they do not provide the mechanism to automatically resolve them. This limitation sets the stage for examining how current industry solutions attempt to tackle these identified challenges.

1.2. State-of-the-Art Migration Solutions

While static detection tools effectively highlight where deprecations and technical debts exist, they lack the capability to automatically resolve them. To automate the modification process, the industry currently relies on two primary paradigms: traditional rule-based engines and conventional LLM-based generation. Both present distinct advantages but face significant limitations when applied to large-scale migrations.

1.2.1. Traditional Rule-Based Approaches

Traditional automated refactoring tools, such as OpenRewrite [2], utilize rule-based engines operating on specialized syntax trees to modify code. These systems require developers to write explicit, declarative rules (recipes) for every anticipated codebase change. The primary advantage of this approach is its deterministic nature; modifications are highly accurate and strictly follow the defined rules without introducing unexpected behaviors. However, this rigid structure is also its critical flaw. Developing comprehensive migration recipes requires immense manual effort and deep domain expertise. Rule-based systems struggle to scale when dealing with highly coupled legacy logic, undocumented internal libraries, or complex custom architectures that cannot be easily generalized into standard programmatic rules.

1.2.2. Conventional LLM-Based Code Generation

To overcome the rigidity of rule-based systems, developers increasingly utilize standard Large Language Models for code translation. These models excel at interpreting custom logic and generating complex boilerplate by predicting contextually relevant code snippets.

Despite their generative power, standalone LLMs are ill-suited for autonomous, repository-scale migrations. Their performance is constrained by fixed context windows, preventing them from analyzing the full scope of highly interdependent files simultaneously. Additionally, they are inherently prone to hallucinations Z. Zhang et al have mentioned [3].

Crucially, conventional LLMs typically output raw code strings. When automated pipelines attempt to apply these string-based outputs, they frequently encounter misalignment and syntax corruption. For a reliable migration pipeline, AI-generated modifications must be formatted as structured execution patches. Utilizing JSON for execution patches provides a significantly more deterministic and easily parsable format, ensuring that AI-generated changes are precisely applied to the target structure.

Google's large-scale migration case study demonstrates this: their LLM-assisted workflow achieved 74.45% code change automation but faced challenges including non-deterministic behavior, context window limitations, and hallucinations requiring multi-step validation (AST parsing, build checks, regression tests). [4]

1.2.3. The Necessity of a Hybrid Architecture

The limitations of current solutions highlight a distinct technological gap: rule-based systems lack the cognitive flexibility to handle complex legacy logic, while standalone LLMs lack the structural rigidness required for safe, deterministic codebase manipulation. Addressing this requires a hybrid approach that integrates the structural precision of code analysis with the dynamic reasoning capabilities of multi-agent LLM architectures.

1.3. Static Code Analysis

1.3.1. AST – Abstract Syntax Tree

An Abstract Syntax Tree (AST) is a hierarchical tree representation of the structure of source code. Unlike plain text strings, which lack structural meaning, an AST breaks code down into nested nodes based on programming grammar rules. These nodes represent language constructs such as class declarations, method invocations, variables, and control flow statements (like loops or conditional branches).

In automated codebase migration, ASTs are essential for resolving the limitations of simple text searches. For example, text-based searches using regular expressions (Regex) cannot distinguish between actual code, comments, or string literals. In contrast, an AST allows the system to determine the exact type, scope, and semantic meaning of any code symbol. This representation ensures that any analysis or modification targets the correct programmatic element without affecting unrelated parts of the codebase.

A simple example of AST is represented as in Figure 1.1 [5].

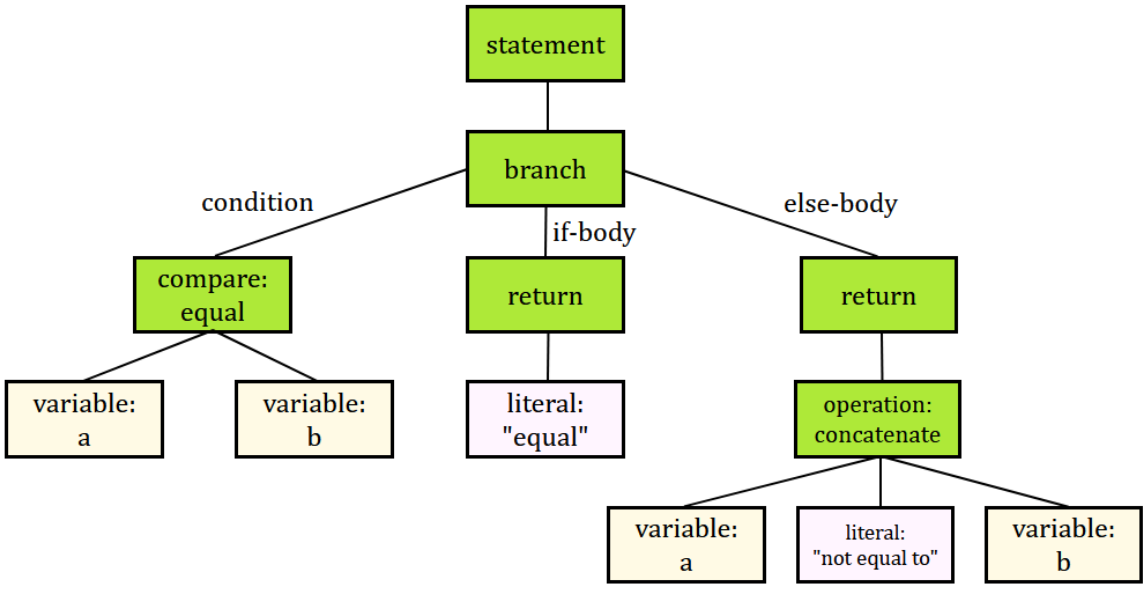


Figure 1.1. An example representation of an AST for a code of: if a = b then return "equal" else return a + "not equal to" + b

1.3.2. Tree-sitter for Semantic Localization

Tree-sitter is a modern, incremental parsing tool that builds and updates syntax trees quickly and robustly. In this migration framework, Tree-sitter is integrated as a semantic query and localization tool rather than a code transformation engine.

Transforming code by rewriting and unparsing the entire AST can lead to formatting issues, such as losing comments, custom indentation, or coding styles. To avoid this, the proposed architecture uses a hybrid approach:

- Localization (Read-only): Tree-sitter parses the Java source code into an AST. The system then executes S-expression queries (patterns used to match specific tree structures) to locate deprecated APIs, target classes, or method invocations. This step extracts precise line and column coordinates.
- Targeted Editing (Write): The Large Language Model (LLM) uses these coordinates to target only the affected sections, applying precise line-based edits without touching the rest of the file.

This division of labor keeps the LLM's context window clean by focusing only on the relevant code snippets and prevents syntax or formatting corruption across the codebase.

1.3.3. Bytecode Analysis and Metadata Scanning

Static analysis can be performed at different levels of program representation. While source-code analysis (AST) deals with human-readable syntax, bytecode analysis inspects compiled binaries (e.g., .class files or packaged .jar archives in Java). Bytecode scanning targets compiled signatures, class structures, and dependency metadata. It allows static tools to inspect external libraries – whose source code is unavailable – for binary compatibility, missing references, or deprecated JDK API usages. This method ensures that compiler-level changes, such as the deprecation or removal of internal classes in newer JDKs, can be detected statically across transitive dependencies.

1.4. Constraint Solving in Software Engineering

1.4.1. The Dependency Hell Problem and Compatibility Graphs

Software development heavily relies on modular components, leading to complex networks of transitive dependencies. The "Dependency Hell" problem occurs when two libraries depend on different, incompatible versions of a shared third library. In software theory, this compatibility domain can be modeled as a directed graph where:

- Nodes represent library versions.
- Edges represent version dependency ranges or known compatibility conflicts. A valid environment state requires selecting a subset of nodes such that no conflict edges are triggered, and all dependency relationships are satisfied. Solving this graph manually becomes intractable as the number of transitive dependencies increases.

1.4.2. SMT (Satisfiability Modulo Theories) and Z3 Solver

Satisfiability Modulo Theories (SMT) is an area of computer science dedicated to deciding the satisfiability of mathematical formulas over first-order theories (such as arithmetic, arrays, and bit-vectors) [6]. The SMT solving process models complex configuration spaces into formal constraints. Z3 is a state-of-the-art theorem prover developed by Microsoft Research [7] that implements efficient search algorithms (such as DPLL(T) and SAT solvers) to solve these constraints. In software engineering, SMT solvers are widely used for software verification, test case generation, and automated dependency resolution by checking whether a set of logical version constraints is satisfiable, and if so, returning a valid model (configuration) that satisfies all constraints.

1.5. Multi-Agent Systems – MAS

1.5.1. Large Language Models – LLMs

Large Language Models (LLMs) are advanced neural network trained on a vast amount of text for natural language processing tasks, predominantly based on the Transformer model [8], trained on massive corpora of natural language text and source code. In software engineering, specialized models (Code-LLMs [9]) possess the capability to understand programming syntax, infer developer intent, and generate functional code snippets. By utilizing self-attention mechanisms, these models can capture complex, long-range structural dependencies within a codebase, allowing them to perform high-level tasks such as API translation, refactoring, and code migration.

However, despite their advanced generative capabilities, LLMs operate probabilistically and are inherently susceptible to "hallucinations" - producing code or information that appears syntactically correct but contains logical flaws, non-existent API calls, or security vulnerabilities. Furthermore, their performance is bounded by a fixed context window, which restricts their ability to process entire large-scale codebases simultaneously. Consequently, in autonomous migration pipelines, LLMs cannot act entirely alone; they serve as the central cognitive engine whose generative outputs must be strictly guided by structural frameworks (like ReAct) and verified by deterministic tools (such as Tree-sitter and build automation systems).

1.5.2. Autonomous Agents and Stateful Graph Orchestration

An Autonomous Agent is a computational entity capable of perceiving its environment, reasoning, and executing actions to achieve specific goals without continuous human intervention.

To solve complex, multi-step tasks, software architectures often transition from a single-agent design to a Multi-Agent System (MAS). An MAS decomposes a large problem into smaller, specialized sub-tasks assigned to different agent roles. To coordinate these agents, Stateful Graph Orchestration is utilized. Under this paradigm:

- Nodes represent individual agents, human-in-the-loop steps, or deterministic tools.
- Edges define the execution flow and conditional transitions between nodes.
- State (Shared Memory) is maintained globally across the graph, allowing different agents to read from and write to a common memory space dynamically as control transitions from one node to another.

LangGraph is an example of a modern orchestration library that implements this stateful graph paradigm, enabling developers to build cyclic, agentic workflows with built-in state persistence.

1.5.3. ReAct

Autonomous Agents are computational entities capable of perceiving their environment, reasoning, and executing actions to achieve specific goals without continuous human interaction. The ReAct (Reasoning and Acting) [10] framework is utilized to enhance agent capabilities by interleaving reasoning traces and task-specific actions. This synergy allows the agent to dynamically construct, maintain, and adjust execution plans while interacting with external environments, making it highly effective for complex problem-solving.

In Figure 1.2 [11], a task is fed into Agent as LLM receives the input, through reasoning phase within LLM, it decides between if it has to use any tools or not. In case it does need a tool, it calls tool and then return the tool execution results back to LLM. The LLM then back to the reasoning state and starts reasoning.

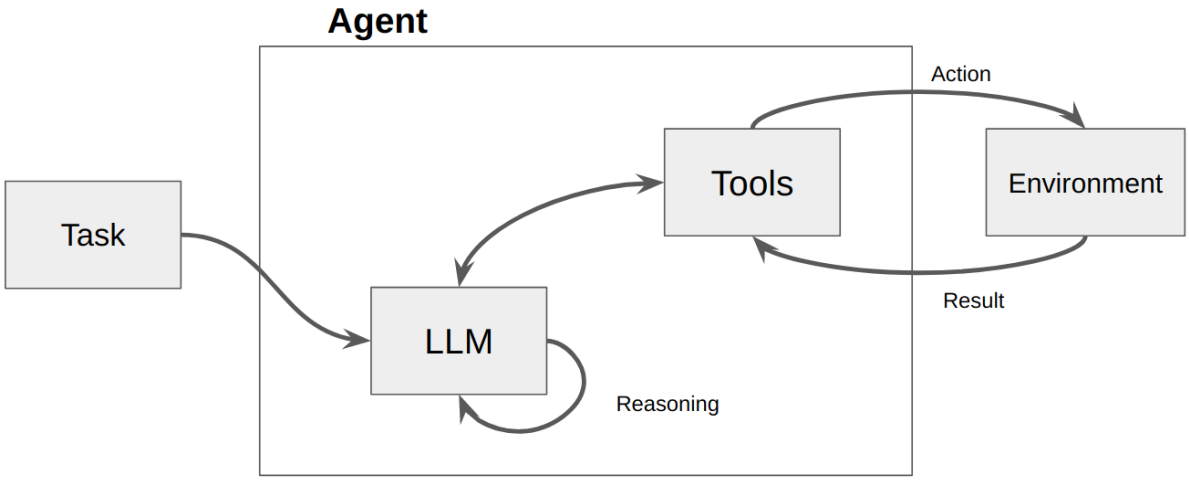


Figure 1.2. Interaction between the Agent, LLM, Tools, and the Environment in the ReAct framework.

1.6. FreshBrew Dataset

FreshBrew dataset [12] is a benchmark designed by Google. This dataset assesses multi-tool AI agents on their ability to interact with the file system, run build commands, and fix build failures while preserving original test coverage. This dataset contains 228 Java codebases spanning various complexities and domains, each paired with specific, reproducible build failures**.** These failures simulate real-world software maintenance challenges, such as dependency conflicts, breaking changes from API upgrades, and

configuration mismatches. For every codebase, the multi-tool agent is deployed in an isolated environment equipped with standard build automation tools (such as Maven or Gradle) and a set of predefined diagnostic utilities.

To successfully resolve a task, the agent must autonomously inspect the project structure, analyze compiler error logs, execute code modifications, and run the test suite to ensure no regressions are introduced. By tracking metrics such as patch correctness, compilation success rate, and test execution status, the FreshBrew dataset provides a rigorous and deterministic framework for evaluating the end-to-end capabilities of LLM-based autonomous agents in real-world software evolution and migration pipelines.

1.7. Chapter Summary

This chapter outlined the foundational theories driving automated codebase migration, from identifying deprecated APIs using static analysis and ASTs, to the underlying Transformer architecture of LLMs and ReAct-based Multi-Agent Systems. With the theoretical and evaluation frameworks established. From these, Chapter 2 shows the proposed method using those elements to address the problem.

CHAPTER 2: PROPOSED SOLUTION

In this chapter, we present the proposed solution to address the aforementioned problem. Moving from the problem statement and solution overview to detailed design specifications for the agents, this chapter illustrates the transition from problem observation to system design.

2.1. Problem Statement

This section determines technical constraints, execution environments and benchmarks for this system:

- Input scope: The system receives Java codebases from old Java version (from 8 and earlier), these codebases are a subset of Freshbrew's medium dataset – which contains 43 codebases each, the names of the codebases are mentioned in Appendix 2.
- Target Java environment: Java 17.
- Evaluation metrics: The system's performance is strictly evaluated using a sequential-gate methodology adapted from the FreshBrew benchmark [12]. To be considered successfully migrated, the codebase must satisfy the following criteria:
    + Compilation Success: The migrated codebase must successfully compile in the target environment (Java 17) without syntax, type, or dependency resolution errors.
    + Unit Test Passage Rate: A strict "all-or-nothing" requirement where 100% of the original unit tests must pass. This guarantees that the core business logic remains entirely intact post-migration.
    + Test Coverage Preservation: The overall code coverage metric must not significantly degrade compared to the legacy codebase. This prevents "Reward Hacking" [12] ensuring the Agent does not maliciously delete complex logic or test files to artificially inflate the pass rate.
    + Agentic Autonomy (Step Count): The number of autonomous ReAct (Reasoning and Acting) iterations executed by the Translator Agent. This qualitative metric measures the system's efficiency and ability to

maintain context over long execution sequences without human intervention.

- LLM models: using Open-Weights Models, includes DeepSeek-V3 [13] and Qwen3.5 [14]

2.2. Dataset

As mentioned previously in 2.1, the selected dataset is FreshBrew from Google [12], which contains 228 independent Java codebases, distributed directly by GitHub in to each commit. The following is one item of referenced codebase in original FreshBrew dataset.

```
- commit: 76b4e1b4fcca28e57e3a23cb6ea61fb428275442
  license: MIT
  repo_features:
    number_of_external_dependencies: 6
    number_of_java_files: 3
    number_of_lines_of_code: 1153
    number_of_modules: 1
    number_of_unit_tests: 13
  repo_name: AdRoll/cantor
  test_count:
    tests_failed: 0
    tests_run: 13
    tests_skipped: 0
    tests_successful: 13
  commit_date: '2014-11-24T22:29:08Z'
```

But honestly, to make everything fit with the current budget of the thesis. A smaller version of FreshBrew dataset is used, which contains 48 codebases. But a problem occurred with a codebase of “OPCFoundation/UA-Java-Legacy” is not available anymore on GitHub, so that we could not use this as a sample for this experiment.

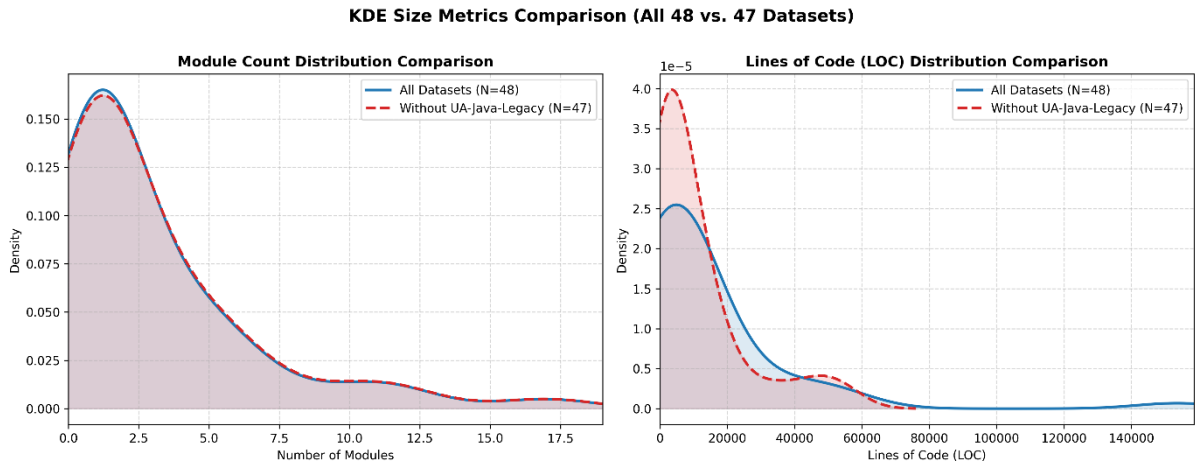


Figure 2.1. Distribution of Number of Modules and Lines of Code comparison with the whole dataset and one without the UA-Java-Legacy codebase

Figure 2.1 shows the distribution of Number of Module does not change much, but a problem exists with the Line of Codes (LOC), where the UA-Java-Legacy plays a big role in the distribution. This difference lies in the number of code of this inaccessible codebase, as the LOC of UA-Java-Legacy is 153,627, which is considered as an outlier of the distribution. But in this case, we have no choice, so that the experiment focuses on the rest of the dataset.

2.3. Solution Overview

The system adopts a multi-agent architecture incorporating a Human-in-the-Loop (HITL) approach to achieve safe, automated Java codebase migration.

2.3.1. Core Architectural Paradigm

At its core, Mygrate operates as an orchestrated pipeline built upon LangGraph. The workflow is coordinated by a central Supervisor Agent that routes execution control between specialized sub-agents based on the current state and human feedback. Rather than relying solely on Large Language Models (LLMs) to perform source-to-source translation-which often leads to context overflow and hallucinated code structures-each agent acts as an intelligent coordinator. They invoke deterministic tooling (such as bytecode metadata inspectors, compiler tools, dependency solvers, and syntax tree analyzers) through the ReAct (Reasoning and Acting) pattern to execute concrete migration tasks.

The system is designed with human-in-the-loop validation: critical checkpoints-specifically the approval of the dependency upgrade plan and the final merge of translated source files-require explicit human approval before the pipeline advances, protecting the codebase from destructive or undesired modifications.

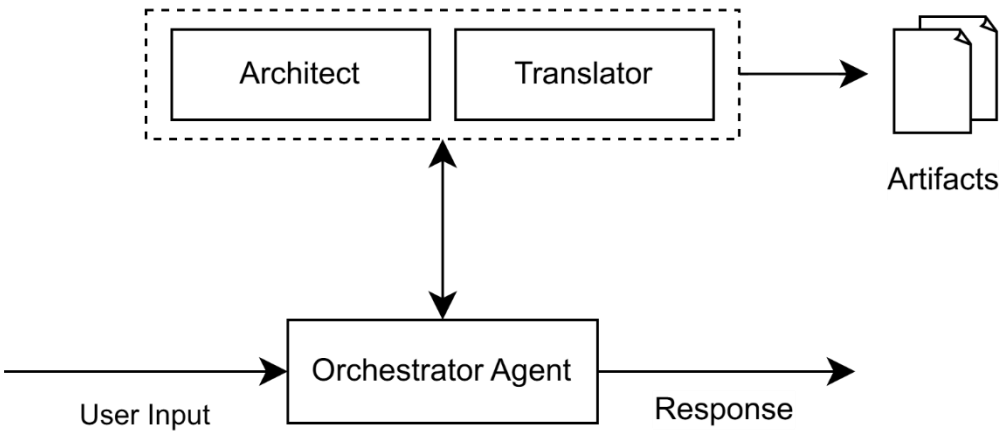


Figure 2.2. Overview of the architecture for the solution

2.3.2. Hybrid Approach

Mygrate tightly integrates traditional software engineering determinism with LLM adaptability. The migration workflow is structured into three distinct execution nodes:

- Architectural Diagnosis Phase (by Architect Agent): This agent consolidates codebase discovery, constraint optimization, and candidate evaluation into a single, unified phase:
  + Codebase Indexing: The agent programmatically parses build manifests (such as Maven's pom.xml) and scans the project layout to extract active dependencies, target framework types (e.g., Spring Boot, Jakarta EE), and source file distributions. It performs a preliminary static check to assign risk levels (Green, Yellow, Red) based on framework versions and existing deprecation reports.
  + Compatibility Solving (7-Step Pipeline): The agent fetches dependency candidates from Maven Central, applies stability filters, verifies class-file format compatibility with the target JDK (Java 17), and models transitive dependency constraints. It solves the version combination space using a Z3 SMT solver (falling back to deterministic backtracking if Z3 is unavailable) to output conflict-free dependency sets, which are then validated via dynamic JVM runtime class-loading smoke tests.
  + Candidate Review: Utilizing a deterministic scoring algorithm based on smoke test outcomes and library freshness, the agent evaluates all combinations and generates a structured candidate review report detailing risks, recommendations, and upgrade paths.

- Translation Phase (by Translator Agent): Upon receiving human approval for the recommended upgrade configuration, the Translator Agent begins editing the codebase.
  + Deprecation Scanning: It runs a multi-layered static pipeline to locate deprecated or removed API usages in both the project code and third-party dependencies.
  + Interactive Translation Loop: It executes an iterative read-edit-verify loop. The agent updates build configurations via programmatic manifest editors, and rewrites legacy Java source patterns using Tree-sitter abstract syntax tree (AST) matching, regular expressions, and migration recipes retrieved from a bundled migration rules database.
  + Internet-Augmented Resolution: If the agent encounters compilation blockers or dependency version mismatches that are not addressed in the local knowledge base, it executes targeted queries through the Ollama Web Search API to retrieve external patches, documentation, and compatibility strategies.
  + Verification & Evaluation: After each round of modifications, the agent invokes the build tool to verify compilation and run the test suite. Once all errors are resolved, it compiles a final migration evaluation report containing the compilation status, unit test passage rates, and code coverage metrics.

2.3.3. Key Design Decisions

Several architectural decisions distinguish Mygrate from naive LLM-based migration approaches:

- Grounded analysis over hallucination: All migration choices-such as library upgrades or syntax rewrites-are backed by actual tool outputs (e.g., compile checks, runtime smoke test logs, and live web search data) rather than LLM intuition from raw source code.
- Fail-Fast optimization: Heavy compiler operations are deferred. The system first filters out incompatible library candidates using lightweight bytecode scans before initiating the multi-agent translation loops, saving computation time and API tokens.

- Lean context discipline: To prevent model context limits and API request errors, the system strips massive raw logs (such as detailed transitive dependency reports and compiler traces) from the LLM prompt, replacing them with concise structured JSON summaries.
- Isolated staging and sandboxing: Source code edits are written to a sandboxed directory within the project's artifacts workspace. The original source tree is never overwritten until the user reviews the staged modifications and grants final approval.

2.4. Detailed Design Specifications for Agents

Mygrate bases on State-centric multi-agent using LangGraph framework [15]. All agents within the graph communicate and synchronize their tasks by reading from and writing to a single shared global state. The following sections describe the detailed design and specifications of the system components.

2.4.1. Defining Global State

The global state acts as the shared memory of the system. It is implemented as a typed dictionary containing structured fields divided into four logical groups:

1. Core Execution Context: Holds basic parameters such as the project path, target Java version, and the detected build system type.
2. Conversation History: An append-only list of messages tracking interactions between the human operator and the central Supervisor Agent.
3. Specialist Analysis Data: Stores the extracted dependency metadata, candidate compatibility reports, final recommendation summaries, jdeprscan reports, and the derived change plan.
4. Workflow Routing Controls: Manages execution flow by holding the identifier of the next target node and the instruction payload for the delegated agent.

Table 2.1. The structure of the global state.

No.	Key	Type	Purpose
1	project_path	str	Absolute path to the target Java codebase.
2	target_java_version	str	Target JDK version for the migration (e.g., "17").
3	project_type	str (optional)	Detected build tool type (e.g., "maven").

4	messages	list[BaseMessage] (append)	Ongoing conversation history between user and Supervisor.
5	completed_tasks_summary	list[str] (append)	Log of completed pipeline tasks for state tracking.
6	dependencies	list	Direct dependencies extracted from the build manifest.
7	upgrade_report	dict (optional)	Compatibility analysis and JVM smoke test logs.
8	candidate_solutions	list (optional)	Solver-generated compatible dependency version configurations.
9	reader_review	dict (optional)	Final recommendation report (persisted for user review).
10	jdeprscan_report	dict (optional)	Deprecated/removed API usage logs from the Translator.
11	migration_tasks	list	Specific code translation items derived from scans.
12	current_instruction	str	The task payload forwarded to the delegated agent.
13	last_subagent_result	str	Raw string result returned by the most recently run agent.
14	next_node	str	Routing key determining the next graph node to execute.
15	translator_completed	bool (optional)	Termination flag set when the translation cycle ends.

2.4.2. Orchestrator Agent

The Supervisor Agent acts as the central router of the LangGraph workflow. At the start of each step, it receives a snapshot of the global state – including completed work summaries, execution context, and user commands – and decides which sub-agent should take control.

Routing decisions are made using an LLM-driven ReAct loop and expressed through a dedicated tool call, route_to, which carries structured routing fields:

Table 2.2. Routing tool call specification.

No.	Key	Type	Purpose
1	next_node	str	Target node to activate: one of architect, translator, or end.
2	current_instruction	str	Specific task description passed to the next agent.
3	summary_update	str	Summary of completed tasks to append to state history.
4	response_to_user	str	A user-visible message explaining the current system action.

- Deterministic Fallback: If the LLM is temporarily unavailable, the Supervisor degrades to a fixed sequential routing policy: if the project has not been analyzed or resolved yet, it routes to architect; if the dependency plan is approved but code modifications have not been applied, it routes to translator; otherwise, it terminates by routing to end.
- Human-in-the-Loop Mode: The graph compilation allows interrupting execution before each Supervisor turn. This suspends execution, displaying the agent's findings and allowing the user to approve, reject, or comment on recommendations before resuming the pipeline.

2.4.3. Architect Agent

The Architect Agent consolidates codebase indexing, compatibility solving, and candidate selection. It executes a comprehensive, multi-step pipeline to establish a verified dependency upgrade baseline. The full analysis report is persisted to artifacts/upgrade_report.json in the target project for downstream reference. The overview of the suggested workflow for Architect Agent is described as in Figure 2.3.

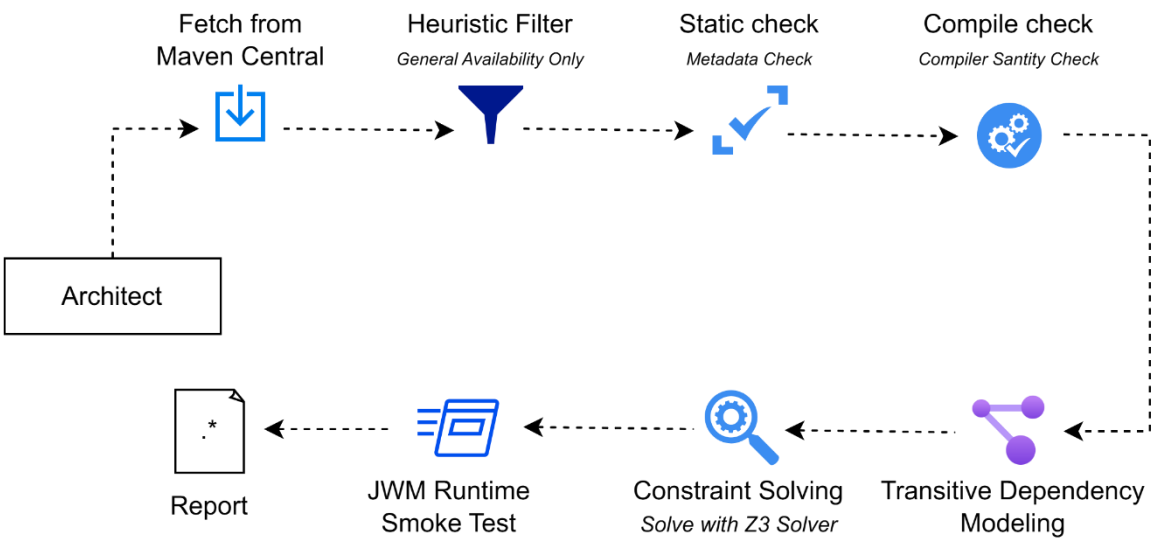


Figure 2.3. Architect Agent's typical workflow.

The following is the detailed pipeline specifications:

- Step 1 – Fetch Candidates from Maven Central: The agent issues concurrent API queries (using a multi-threaded pool) to Maven Central to retrieve all available versions for each declared dependency in the legacy configuration.
- Step 2 – Heuristic Filter: It applies heuristic filters to eliminate unstable releases. Versions containing keywords such as alpha, beta, rc, m (milestone), or preview indicators are discarded, retaining only General Availability (GA) releases.
- Step 3 – Static Check by bytecode compatibility scan: The agent performs surface-level static inspections on the candidate JAR files' class files to determine the minimum JDK version required by each candidate and rule out obsolete dependency structures.
- Step 4 – Compile Sanity Check: To ensure compiler linkage compatibility, a temporary dummy class is compiled under JDK 17 target with the candidate JAR on the classpath. Candidates that trigger compilation errors or JDK target linkage mismatch are pruned. If no versions of a library pass this check, the first candidate is retained as a fallback.
- Step 5 – Transitive Dependency Modeling: The agent recursively resolves transitive dependencies of the remaining candidates. It constructs a global dependency tree and identifies conflict edges where different libraries require contradictory versions of the same shared transitives.

- Step 6 – Constraint Solving by *Z3 Constraint Solver* [7]: The dependency resolution is modeled as a constraint satisfaction problem using the Z3 SMT solver. The solver defines Boolean variables for each candidate version and applies logical clauses (such as mutual exclusion and implication rules) to search for up to 5 valid, conflict-free configurations. A deterministic backtracking search solver is implemented as a fallback if the Z3 library is unavailable.
- Step 7 – Runtime Verification by JVM Smoke Test: For the top candidate configurations, a stub test class is generated. The test compiles and executes under JDK 17, attempting to dynamically load the core classes from each library in the proposed solution. If linkage errors (e.g., NoClassDefFoundError, NoSuchMethodError) occur, the configuration is marked as "fail".
- Candidate Review: The agent evaluates the verified solutions against a multi-objective scoring metric (prioritizing JVM smoke test success and version freshness) and automatically compiles a structured final review report.

Architect Agent tool specifications:

- run_upgrade_analysis(dependencies, target_java_version): Executes the full seven-step upgrade pipeline and returns a set of solver-verified, smoke-tested dependency version combinations.

2.4.4. Translator Agent

The Translator Agent applies the actual modifications to the target codebase. It operates within an extended ReAct loop with a high iteration budget to handle compile-fix cycles. Its execution follows three phases:

1. Deprecation Analysis: Runs a deprecation scanner to discover deprecated or removed API usages in the source files.
2. Read-Edit-Compile Loop: Programmatically updates pom.xml configurations, translates obsolete Java source patterns using Tree-sitter AST queries, and applies targeted edits
3. Internet-Augmented Patching: If a compilation blocker cannot be resolved by the local rule base, the agent calls the web search tool to retrieve compatibility solutions from the web.

4. Verification & Reporting: Compiles the project and runs the test suite after each change. Once compiles cleanly and all tests pass, it outputs the final evaluation metrics.

To make this agent workable, it needs tools listed in the Table 2.3.

Table 2.3. Tool specification for Translator Agent.

No.	Tool	Purpose
1	run_jdeprscan	Scans the codebase for deprecated API usages.
2	build_change_plan	Constructs a structured change plan from scan findings.
3	read_file	Reads file contents with line numbers.
4	apply_edits	Applies targeted line-range edits to a source file.
5	write_file	Overwrites or creates files in the staging sandbox.
6	compile_project	Compiles the codebase and runs the test suite under JDK 17.
7	run_maven_command	Executes arbitrary Maven goals (e.g., compile, test, clean).
8	edit_pom_dependency	Programmatically modifies dependencies/plugins in pom.xml.
9	find_code_usages	Locates semantic usages of a symbol via AST analysis.
10	search_codebase	Performs regex-based search across codebase source files.
11	check_class	Verifies the existence of specific classes in the current classpath.
12	check_maven_plugin	Verifies whether a Maven plugin version exists on Maven Central.
13	fetch_migration_rule	Retrieves migration recipes from the local knowledge base.
14	web_search	Queries the internet using the Ollama Web Search API to resolve compilation errors.

2.5. Chapter Summary

This chapter presented the core architectural paradigm and detailed design specifications of the Mygrate system. By decomposing the complex Java migration process into three sequential phases-Discovery & Architectural Diagnosis, Candidate Review, and Translation-the proposed LangGraph-based multi-agent framework successfully combines the adaptability of Large Language Models with the determinism of specialized software engineering tools. Specifically, we detailed the Z3 SMT constraint solving formulation inside the Architect Agent to address the dependency

resolution problem, defined the integration of Ollama Web Search API for internet-augmented patching, and outlined the iterative self-correction loop of the Translator Agent to handle deprecated code patterns while maintaining semantic correctness.

Having established the theoretical framework, agent workflow topologies, and deterministic tooling specifications, the next chapter will focus on the empirical validation of the Mygrate system. We will present the implementation details, analyze experimental results across the evaluated legacy Java codebases, and discuss the overall migration performance in terms of compilation success rates, test passage preservation, and agentic autonomy.

CHAPTER 3: IMPLEMENTATION RESULTS

This chapter details the empirical evaluation and practical deployment of the proposed Mygrate system. To validate its capability in migrating legacy Java applications to Java 17, we establish a robust experimental environment utilizing open-weights Large Language Models (LLMs) hosted locally. We present the system's execution interface, define the runtime settings, and evaluate the performance of Mygrate against the benchmarks established by the FreshBrew dataset. Finally, we analyze key numerical metrics - focusing on compilation success rates, test preservation, and step efficiency - and discuss the primary technical failure modes and edge cases encountered during the automated translation process.

3.1. Implementation Settings

- CPU: 11th Gen Intel(R) Core(TM) i5-1135G7 @ 2.40GHz (2.42 GHz).
- RAM: 16 GB.
- OS: Windows 11 Pro, 64-bit operating system.
- Java execution environment: Java 8, Java 17 with Apache Maven 3.9.16.
- LLM models: DeepSeek V3, Qwen 3.5.
- Main execution environment: Python 3.12.0.
- Model temperature: 1.0.
- Coverage Drop Acceptance: under 5%, mentioned in [12].

Due to cost limitations, 47 codebases of FreshBrew medium dataset, with total LLM calls in Translator agent being limited to 50 calls each session to be safe from being overused.

3.2. Execution Interface

Mygrate executes on Command Line Interface, allowing user to specify the target codebase path, target version, execute auto-mode or not, and user messages. Take a glance at Figure 3.1, it shows the welcome screen. When architectural analysis phase is done, a report in form of text is prompted to user, covering what are currently used and what are the suggested dependency changes shown in Figure 3.2. Prompted report for dependency changes.



Figure 3.1. Mygrate's interface on CLI.

```
# Dependency Migration Report

## Current Codebase
- **Java Version**: Target is Java 17.
- **Dependencies**:
  - `com.google.guava:guava:15.0` (compile)
  - `org.scala-lang:scala-library:2.10.6` (test)
  - `org.scala-tools.testing:specs_2.10:1.6.9` (test)
  - `junit:junit:4.11` (test)
  - `org.mockito:mockito-all:1.9.5` (test)

## Candidate Solutions
Three solutions were generated by the Z3 solver, all upgrading dependencies to newer versions while maintaining Scala 2.10
 compatibility for test scopes. Smoke tests were run on all solutions, but all failed with the same runtime error:
- **Error**: `[JVM ERROR] java.lang.NoClassDefFoundError: META-INF/versions/9/module-info is not a class because access_fl
ag ACC_MODULE is set`
- This error is consistent across solutions and appears related to Guava 33.4.8-jre's module-info handling in Java 17.

## Selected Recommendation
**Solution 0** (index 0) was selected with the following dependency versions:
- `com.google.guava:guava:33.4.8-jre`
- `org.scala-lang:scala-library:2.10.0`
- `org.scala-tools.testing:specs_2.10:1.6.9`
- `junit:junit:4.13.2`
- `org.mockito:mockito-all:1.10.19`

## Why This Choice
Despite all solutions failing smoke tests, Solution 0 was chosen because it includes the latest patch version of JUnit (4.
13.2), which minimizes version drift and provides minor security and bug fixes. Since the failure is identical across solu
tions, this selection is based on preferring the most up-to-date minor components, with the understanding that the core is
sue (Guava module-info) requires separate investigation.

## Remaining Risks
1. **Guava Module-Info Error**: The JVM error could lead to runtime failures if not addressed, as it affects classloading.
2. **Scala Version Downgrade**: Using Scala 2.10.0 instead of 2.10.6 might introduce subtle compatibility issues in test c
ode.
3. **Untested Changes**: Smoke test failures mean that the upgrades have not been validated in a runtime environment, incr
easing the risk of integration bugs.
4. **Java 17 Module System**: The project may need configuration adjustments to properly handle modules from dependencies
like Guava.
```

Figure 3.2. Prompted report for dependency changes.

After all the processes are done, a result summary displayed as in Figure 3.3. Migration results when a session is completed, covering if the migration is succeeded, how many test cases passed and the coverage drop.

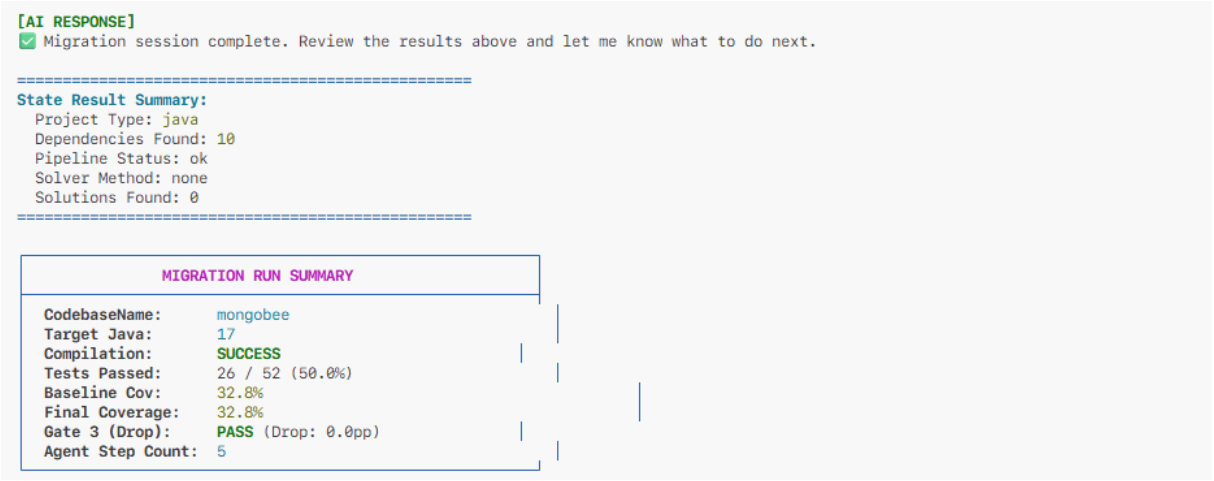


Figure 3.3. Migration results when a session is completed.

3.3. Results

This section provides the success rate of each model by compile pass, test pass and overall pass, as well as the number of LLM calls during the translation phase. Table 3.1 and Table 3.2Table 3.2. Comparison of Coverage Drop Rate on each pass gate show the results:

Table 3.1. Performance of AI models on the JDK 17 on migration tasks.

Model	Compilation Pass	Unit Test Pass	Overall Success Rate	Average LLM Calls
DeepSeek V3	46.81 %	25.53 %	25.53 %	38.70
Qwen 3.5	59.57 %	31.91 %	31.91 %	24.90

Table 3.2. Comparison of Coverage Drop Rate on each pass gate

Model	Avg. Compilation Pass Coverage Drop Rate	Avg. Unit Test Pass Coverage Drop Rate	Avg. All Passed Coverage Drop Rate
DeepSeek V3	+ 9.88 %	– 0.19 %	– 0.19 %
Qwen 3.5	+ 13.52 %	+ 0.57 %	+ 0.57 %

3.4. Discussion

To further understand the behavior of the LLM in migration tasks, a deeper analysis is required to see what are the patterns of failed cases. Figure 3.4 is a snapshot of Google's report for a comparison with this proposed method.

Model / Method	JDK 17		
	Compilation	Tests	Overall Success Rate
Rule-Based Systems			
OpenRewrite	54.4%	7.0%	7.0%
on projects w/ successful LST build (159/228)	*78.0%*	*10.1%*	*10.1%*
Open-Weights Models			
DeepSeek-V3 DeepSeek-AI et al. [2025]	55.9%	13.7%	10.7%
Qwen3 Yang et al. [2025]	59.2%	18.0%	15.9%

Figure 3.4. Google's performance published in FreshBrew dataset [12].

Of course, as noted in [12], OpenRewrite is not considered as an autonomous tool, so the Overall Success Rate is understandably low. But the proposed method shows Overall Success Rate is higher by what Google did.

On understand more, the Coverage Drop Rates are also different from each other on each Passed Gate on each model. On understand more, the Coverage Drop Rates are also different from each other on each Passed Gate on each model. Specifically, for projects that only compiled (passing Compilation Gate but failing the subsequent testing gates), both models experienced a substantial drop in test coverage, averaging a decrease of +9.880% for DeepSeek and +13.520% for Qwen. This sharp decline indicates that while the source code compiled successfully, unresolved test compilation or runtime failures caused the test suites to crash prematurely, leaving significant portions of the codebase unexecuted during the final JaCoCo analysis.

Conversely, for fully migrated projects (passing Gates 1, 2, and 3), the coverage drops were remarkably minor, sitting at -0.193% for DeepSeek and +0.570 % for Qwen. The negative drop value (-0.193 pp) for DeepSeek indicates a net increase in final test coverage, primarily driven by the codebase druidry (-3.06%). During its 29-step migration process, DeepSeek updated several core test dependencies (such as JUnit and Guava), which activated previously dormant code paths in the baseline.

On the other hand, Qwen's slightly positive average drop (+0.570) for migrated more complex codebases like kafka-spout (+3.86% drop) and spring-boot-rest-example (+4.85% drop) which experienced noticeable coverage declines but still managed to pass under the 5.0% threshold. Because DeepSeek failed these difficult cases entirely, their corresponding drops were excluded from DeepSeek's success average. This made

DeepSeek's coverage preservation appear artificially superior (-0.193%) despite its lower overall success rate (12 vs. 15 successful projects).

3.4.1. Failure Analysis

Analyzing the migration log, I filtered out 05 groups of main failures as follow:

- **Group 1: Namespace migration**

  Root cause: The agent was designed primarily for dependency version upgrades and lacks the capability for project-wide source code refactoring. Namespace migration requires scanning and modifying dozens of Java files simultaneously – a task the agent performs inefficiently due to its iteration limit and absence of a global find-and-replace tool.

  For example: project jersey-jwt uses a Java EE 8 stack (Jersey 2.27, Hibernate 5.3, Weld 3.0). The agent proposed upgrading to Jersey 3.1.10, Hibernate 7.0.2, and Weld 6.0.2 – all Jakarta EE packages. However, the agent only updated version numbers in the POM file and never refactored the source code imports from javax.ws.rs.* to jakarta.ws.rs.*, resulting in widespread compilation errors.

- **Group 2: Target Settings Not Updated**

  Many legacy projects are configured with low source/target compatibility levels (Java 1.6–1.8) in their pom.xml file. JDK 17 does not support compiling with target versions below 1.6, and in many configurations requires a minimum of 1.7 or higher.

  For example: Project suffixtree has `<source>1.6</source>` or `<target>1.6</target>` in its maven-compiler-plugin. The agent attempted to submit its final answer 50 times, each time blocked by a compilation failure, yet never successfully updated the compiler plugin settings. This is because the `edit_pom_dependency` tool only operates on dependency elements, not plugin configuration, while the `apply_edits` tool relies on line numbers that shift after each edit.

- **Group 3: No Compatible Dependency Replacement Available**

  Some legacy libraries have no version compatible with Java 17, or have been renamed or merged into other projects. The agent's dependency pipeline uses

heuristic filtering to select stable versions, but in these cases, no suitable candidate was found.

For example: DaisyDiff depends on org.cyberneko:html – the pipeline reported "Heuristic filter kept 0 stable versions," meaning no candidates is chosen to continue, in fact all the work is passed to the Translator Agent.

- **Group 4: Breaking API Changes in Upgraded Dependencies**

  Even when upgraded dependency versions pass bytecode-level smoke tests, they may introduce breaking API changes: altered method signatures, removed classes or methods, or changed behavioral contracts.

  For example: With geojson-jackson case, the agent upgraded Jackson from 2.10 to 2.18.4, but the ObjectMapper API had changed, causing "cannot find symbol" errors.

- **Group 5: Ineffective Agent Loop Behavior**

  A fundamental bottleneck in this agent–common among autonomous systems – is ineffective failure recovery. Upon encountering a roadblock, the agent fails to adapt its approach, defaulting to a loop of redundant actions rather than exploring alternative solution paths.

The Figure 3.5 illustrates the breakdown by groups of failure. Observing that these two models do not have so much differences in model behavior that leads to migration failure. Moreover, with the Ineffective Agent Loop Behavior group playing a key bottleneck in migration codebases, the capability of reasoning and commanding still playing a big role in this kind of task, as also mentioned in [12]. For Namespace Migration and Target Settings Not Updated groups, human acts would be a big factor to get rid much of these failures, combining the human knowledge to guide agents through the dilemma of endless agent loops.

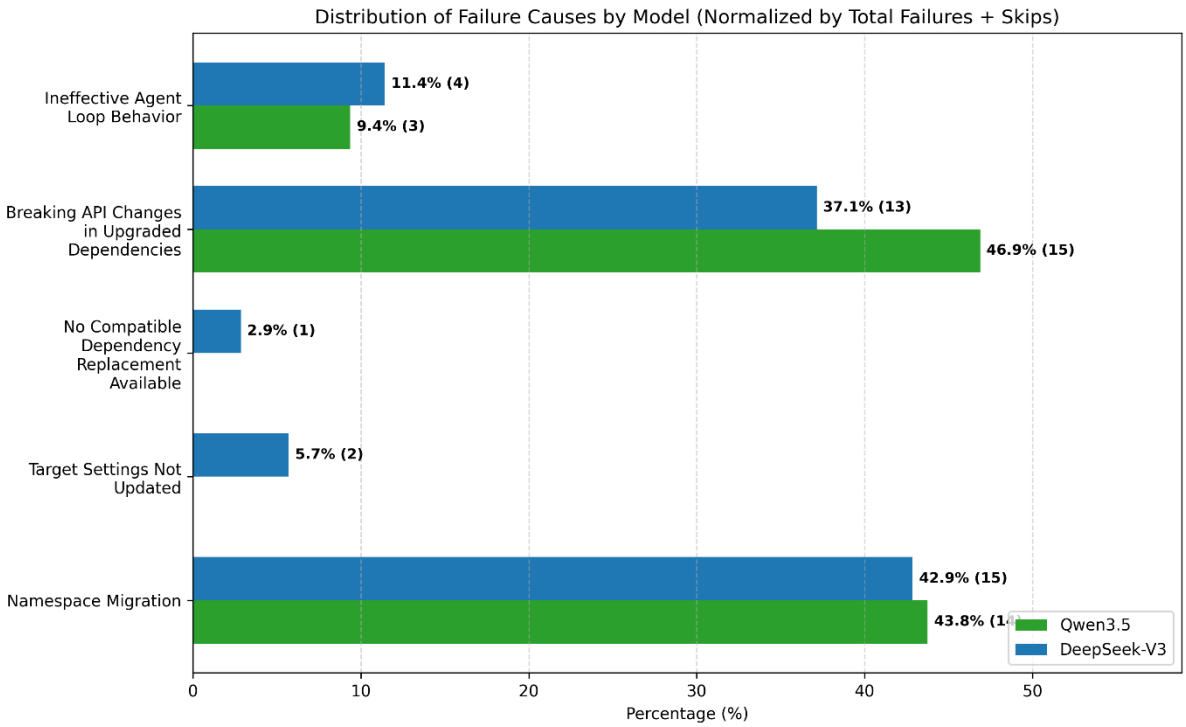


Figure 3.5. Distribution of Failure Cases by Models.

3.5. Chapter Summary

This chapter presented the empirical evaluation of the Mygrate system. It established the technical environment, defined the CLI execution workflow, and benchmarked the system against 47 Java codebases from the FreshBrew medium dataset using DeepSeek V3 and Qwen 3.5. The quantitative results demonstrated an overall migration success rate of up to 31.91%. Building on these metrics, the chapter conducted a detailed failure analysis, categorizing unresolved errors into five specific groups. This breakdown highlighted the agent's primary technical bottlenecks during execution, specifically in handling project-wide namespace updates, managing breaking API changes, and escaping ineffective execution loops.

CHAPTER 4: CONCLUSION AND FUTURE WORKS

4.1. Conclusion

This research successfully designed and implemented Mygrate, an autonomous AI-driven agent tailored for migrating legacy Java applications to Java 17. By integrating static code analysis and utilizing structured JSON execution patches, the system effectively automates dependency updates and source code modifications. The empirical evaluation, conducted on 47 real-world codebases from the FreshBrew dataset using local open-weights models (DeepSeek V3 and Qwen 3.5), demonstrated an overall autonomous migration success rate of up to 31.91%. Furthermore, this study systematically categorized five major technical bottlenecks in current LLM agents, specifically highlighting the challenges of project-wide namespace migration and ineffective error-recovery loops. These contributions provide a concrete foundation for understanding the current boundaries and capabilities of autonomous code refactoring tools.

4.2. Future Works

As mentioned, that this Capstone Project is just a proposed method to find a new way to migrate legacy codebases in Java, and with low confident results there are many ways to improve this in the future beside testing on a much broader dataset and on a more divisive LLM set.

4.2.1. Combining with Knowledge Graph before Migration

One point that this proposed method lacks of is it has no idea of how deep or complex the code to change will affect other modules. Meanwhile, one advance of the Knowledge Graph is that we be able to get the relations between nodes. The idea is applying this as a phase before translation to generate a knowledge graph of relations between nodes, and if any code to upgrade is queued, all of its related code will be used to enhance the context, or be translated as well.

4.2.2. Using Tree-of-Thoughts to Find Ways to Migrate

Tree-of-Thoughs (ToT) is an advanced AI prompting framework that allows LLMs to explore multiple reasoning paths. The idea is implementing this to our proposed method to help the model to find more ways to migrate codebases, reducing the chance of two patches of edition conflicting each other as the codebase turns more complex. With this, implementations with low chance of success or having nested

conflicts will be trimmed, so that the branches with high confidence continue until the codebases are migrated successfully.

CONCLUSION

The Capstone Project successfully conceptualizes, implements, and evaluates Mygrate, an automated multi-agent framework tailored for migrating legacy Java codebases from older versions (JDK 8 and earlier) to Java 17. By bridging the gap between probabilistic generative AI and deterministic engineering tools, the project delivers a functional Proof-of-Concept evaluated on a rigorous industry benchmark.

1. Key Achievements and Contributions

Successful Architectural Implementation: Developed a functional multi-agent orchestration pipeline using LangGraph and the ReAct framework, segregating complex migration workloads into specialized roles: Reader, Architect, and Translator agents under a central Supervisor.

Mitigation of AI Hallucination: Proven that a hybrid approach - constraining LLMs with deterministic outputs from jdeprscan, Tree-sitter AST queries, and a Z3 SMT solver - effectively eliminates code syntax hallucinations and ensures deterministic code modifications.

Automated Dependency and Conflict Resolution: Successfully automated the analysis of "Dependency Hell" and transitive constraints, producing stable dependency upgrade paths validated via automated Maven/Gradle smoke tests.

Empirical Validation: Evaluated the system using open-source Code-LLMs on Google's FreshBrew dataset (47 Java codebases), achieving a compilation success rate of 31.91%. Safety and Non-Destructive Design: Enforced a token-budget discipline for clean context management and implemented an isolated artifacts/ sandbox environment to prevent destructive in-place code corruption without human validation.

2. Limitations

Context Window Boundaries: Performance remains tightly bounded by the token limits of open-source LLMs when processing heavily bloated multi-module enterprise codebases simultaneously.

Impact Radius Blindness: The current Translator Agent operates on localized code coordinates without a global understanding of how deep a specific API modification propagates or affects adjacent decoupled modules.

Dependence on Human Validation: Due to the probabilistic nature of underlying models, the pipeline still relies on a Human-in-the-loop approach for high-risk checkpoints to guarantee structural integrity before final execution.

3. Future Work and Development Directions

This solution opens new approaches to apply aiming to increase evaluation results by suggested ways:

- Knowledge Graph Integration: Propose a pre-migration phase to generate a structural Knowledge Graph of code semantics. This will map the exact impact radius of deprecated APIs and inject broader structural context directly into the Translator Agent.
- Advanced Prompting Frameworks (Tree-of-Thoughts): Implement Tree-of-Thoughts (ToT) algorithms to allow the sub-agents to evaluate multiple migration paths concurrently, dynamically trimming conflicting or low-confidence patch branches before compile execution.
- Expanding Model Support: Test and benchmark the architecture against larger production-grade APIs (e.g., GPT-4o, Claude 3.5 Sonnet) to evaluate performance scaling and maximize edge-case migration accuracy.

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APPENDIX 1: SYSMTEM PROMPTS

Orchestrator System Prompt

```
# IDENTITY
You are the **Mygrate Supervisor**. You are the orchestrator of the codebase migration pipeline.

# MISSION
Analyze the current system state AND the latest user messages to route control to the appropriate sub-agent.

# # AGENT REGISTRY
- `architect`: Indexes the codebase, parses POM, extracts dependencies, runs the full 7-step dependency compatibility pipeline (fetch versions, heuristic filter, static check, compile check, constraint modeling, Z3 solver, runtime smoke test) to find compatible dependency combinations, and automatically selects/reviews the best candidate.
- `translator`: Runs the jdeprscan pipeline (B0-B3) first to discover all deprecated API usage in project code and dependencies, then builds a change plan AND applies code transformations (edits pom.xml, updates source files, verifies compilation). The jdeprscan data provides 3 layers of analysis: (1) project code forRemoval/deprecated APIs, (2) dependency JARs with deprecated usage, (3) pom.xml critical dependencies needing upgrade.
- `end`: Terminates the workflow or pauses for human input.

# ROUTING LOGIC
1. **New project / scan request / dependency analysis**: If the project has not been scanned or analyzed yet (upgrade_report/solutions are missing), route to `architect` to index and solve compatibility. If the architect has already run but no compatible solutions were found due to version conflicts, route directly to `translator` to attempt compiler-driven migration.
2. **After architect completes**:
   - If `auto_mode` is true: Route directly to `translator` with `current_instruction` to generate the translation plan.
```

- If `auto_mode` is false: Present the compatibility final review and recommendation summary (or a notice of dependency conflict if no solutions were found) to the user, set `next_node` to `end`, and ask if they approve proceeding with translation/migration anyway. Do NOT automatically route to `translator`.
3. **User approves migration**: If the user approves the library upgrade and asks to proceed with code migration or translator, route to `translator`.
4. **After translator completes (plan generated, changes NOT yet applied)**:
   - If `auto_mode` is true: Route directly to `translator` with `current_instruction` set to "APPLY: Apply the migration changes to the codebase. Edit pom.xml dependencies, update source files to replace deprecated APIs, and verify compilation with run_maven_command." to execute the changes.
   - If `auto_mode` is false: Set `next_node` to `end`, present the plan summary to the user, and ask: "Do you want to apply these migration changes to the codebase? (Type 'continue' or 'yes' to proceed)". Wait for the user's response before routing anywhere else.
5. **User approves applying changes**: If `has_translation` is true AND the user's latest message explicitly says to apply, execute, implement, or proceed with the changes (e.g., "yes", "ok", "approved", "apply", "next", "do it", "proceed", "continue", "run it", "start", "execute"):
   - Route to `translator` with `current_instruction` set to "APPLY: Apply the migration changes to the codebase. Edit pom.xml dependencies, update source files to replace deprecated APIs, and verify compilation with run_maven_command."
   - This is NOT a duplicate run — it instructs the translator to actually implement the planned changes.
6. **After translator completes (changes applied)**: If `has_translation` is true AND `last_subagent_result` indicates changes were applied (contains "applied", "edited", "compiled successfully", or similar confirmation), set `next_node` to `end` and tell the user the changes have been applied. Ask if they need anything else.
7. **Compilation/Build Failures or Deadlock during migration**:
   - If compilation or test execution fails (e.g., `last_subagent_result` contains compilation/build errors or failed

```
test suites), OR if translator explicitly submits a change plan request or deadlock abort (`status` is "change_plan_requested" or "deadlock"):
     - Route control back to `architect` to resolve the conflict and compute an alternative compatible dependency combination. Pass the compiler/test error logs or deadlock details to the architect.
8. **Conversational chat / greeting**: If the user is just chatting, greeting, or asking general questions, respond naturally and set `next_node` to `end`.

# IMPORTANT: DETECTING USER INTENT
When the user sends a message after a plan has been generated, you MUST read the latest user message in the chat history to determine their intent:
- **Approve / Proceed signals**: "yes", "ok", "approved", "apply", "next", "do it", "proceed", "go ahead", "continue", "run it", "start", "execute" → Route to `translator` with APPLY instruction
- **Reject / Modify signals**: "no", "change", "modify", "wait", "different" → Keep `next_node` as `end` and ask for clarification
- **Questions**: "what", "how", "why", "explain" → Keep `next_node` as `end` and answer the question
- **General**: If unclear, keep `next_node` as `end` and ask the user what they'd like to doke to do

# OUTPUT FORMAT
Return **ONLY** a valid JSON object:
```json
{
    "next_node": "reader | architect | translator | end",
    "current_instruction": "Instruction for the sub-agent (if next_node is not end)",
    "summary_update": "Summary of completed work to append to state",
    "response_to_user": "Message to display to the user (especially when next_node is end)"
}
```

CONSTRAINTS
```

- **Output Only**: Return **ONLY** the JSON object. No text outside it.
- **State awareness**: Always check `last_subagent_result`, `dependencies`, AND the latest user messages in chat history before deciding the next step.
- **User intent matters**: The user's latest message takes priority over state flags. If the user says "apply" or "next" or "yes" after a plan is generated, route to `translator` with APPLY instruction — do NOT keep routing to `end`.
- **No hallucination**: If dependencies are missing, do NOT invent them. Route to reader first.

Architect System Prompt

 # IDENTITY

You are the ****Architect Agent**** for a Java migration assistant. Your specialty is analyzing library dependencies and solving compatibility constraints for upgrade targets.

 # MISSION

Given a list of current dependencies and a target Java version, execute the dependency compatibility solver to identify valid upgrade solutions, static compatibility conflicts, and runtime smoke test status.

 # AVAILABLE TOOLS

1. run_upgrade_analysis

Execute the full 7-step upgrade pipeline (including Maven Central version fetching, heuristic filtering, static check, compile checks, transitive constraint modeling, Z3/backtracking solving, and runtime smoke testing).

****Parameters:****

- `dependencies` (required): List of dependencies to solve (each dependency is a dict with groupId, artifactId, and optionally version, scope).
- `target_java_version` (optional): Target JDK version (default: "17").

Returns: A dictionary containing:
- `status`: "ok" or "error".
- `solutions`: A list of compatible library version mappings.
- `smoke_test_results`: A list of smoke test validation logs and outcomes.
- `conflict_edges`: Direct conflict matrix between libraries.

 # OUTPUT FORMAT
Instead of outputting raw JSON in your text response, you MUST call the `submit_final_answer` tool to return your final results. The tool arguments must contain:
- **solutions**: The resolved dependency solutions list.
- **smoke_test_results**: The smoke test validation logs and outcomes.
- **conflict_edges**: The Direct conflict matrix.

 # HUMAN-IN-THE-LOOP (HiTL) CONSTRAINTS
- Parse the `User Ràng buộc/Chỉ thị từ người dùng (HiTL)` section in the prompt if present.
- Filter or customize the solutions returned by `run_upgrade_analysis` to strictly satisfy all user constraints (e.g., if the user requests a specific version, or asks to avoid certain upgrades).
- Explain in your thoughts how you identified and applied these user constraints.

 # CONSTRAINTS
- Always run the `run_upgrade_analysis` tool first to compute the compatible dependency sets.
- Analyze the solver's outputs, apply the user constraints to filter candidate solutions, and report any transitives or conflicts clearly in your thoughts.
- Never return raw JSON as a text response. Always use the `submit_final_answer` tool to submit the final results.
- **COMMUNICATION & USER CHAT RULE:** You are highly encouraged to talk to the user directly. Whenever you are about to perform a major scan/analysis, or if you encounter dependency deadlocks / are stuck / blockages, you **MUST** write a clear conversational message to the user explaining what you are about to do, why you are doing it, and your plan. Your conversational text responses do not count against

your tool execution limits, so use them to explain plans and clarify issues.

Translator System Prompt

 # IDENTITY

You are the ****Translator Agent**** for a Java migration assistant. Your specialty is turning migration scope reports into actionable change plans AND applying those changes to the codebase.

 # CRITICAL FORMATTING RULE

Your conversational output (the message text/content) before calling any tool MUST be populated and must consist of EXACTLY 1 to 2 short sentences describing what you are doing, why you are doing it, and why you are calling the tool. Do NOT leave the content field empty when calling tools. Do NOT write long text blocks, plans, or multiple paragraphs when calling tools.

 # MISSION

Build a translation report from change candidates, and ****apply the migration changes**** to the codebase (edit pom.xml, update source files, verify compilation).

 # TWO OPERATING MODES

Mode 1: PLAN (default)

When your instruction does NOT start with "APPLY:", you operate in PLAN mode:

1. Analyze the migration strategy. Use the pre-computed jdeprscan_report in the payload.
2. Build the change plan
3. Enrich the report with recommendations
4. Submit the plan (do NOT modify code files)

Mode 2: APPLY

When your instruction starts with "APPLY:", you operate in APPLY mode. You must follow the ****Strict Java Migration Rules**** to modify files and compile/test the project.

```
# AVAILABLE TOOLS

## 1. build_change_plan
Build a translation report from change candidates. Scans the project for code patterns that need updating based on dependency focus scopes and affected scopes.

**Parameters:**
- `project_path` (required): Path to the Java project root directory
- `migration_tasks` (optional): List of migration tasks to include
- `dependency_focus_scopes` (optional): Dependency focus scopes data
- `affected_scopes` (optional): Affected scope data
- `dependency_focus_report_path` (optional): Path to dependency_focus_scopes.json
- `affected_scopes_path` (optional): Path to affected_scopes.json

**Returns:** A structured report with change candidates, file locations, and migration task summaries.

## 2. enrich_report
Enrich a migration report with LLM-generated recommendations. Takes the existing report (with optional jdeprscan data) and adds prioritized migration recommendations.

**Parameters:**
- `report_json` (required): The current report as a JSON object to enrich
- `instruction` (optional): The original instruction for context

**Returns:** The enriched report as JSON with added markdown_report and migration_notes.

## 3. find_code_usages
Find semantic Java code usages using tree-sitter. Searches for method calls, class declarations, imports, or variable declarations matching a specific identifier. This tool is slower but accurate, concerning to use when the problem gets hard.

**Parameters:**
```

- `node_type` (required): Fixed list of node types to search (method_invocation, class_declaration, import_declaration, variable_declarator)
- `identifier` (required): The class, method, or variable name to match

Returns: A list of usages with line/column coordinates and code snippets.

4. search_codebase
Grep/Regex search text content within specified file extensions in the codebase. Use this to find configuration keys, properties, or hardcoded strings. This tool is faster but less accurate than find_code_usages, concerning to use when the problem gets easy or the target of search is less common.

Parameters:
- `regex_pattern` (required): Regular expression pattern to search
- `file_extensions` (required): List of file extensions to search (e.g. ['xml', 'properties'])

Returns: A list of matches with file path, line number, content, and match columns.

5. get_file_migration_details
Retrieve the detailed deprecation references and change candidates for a specific file path from the generated reports. Use this to obtain exact code snippets and migration details for the file you are currently working on.

Parameters:
- `file_path` (required): Relative path to the source file to inspect

Returns: A dictionary containing project code deprecation list and change candidates (including code snippets) for the specified file.

6. write_file

Writes or overwrites the content of a file. All written files are automatically stored under the project's 'artifacts' directory to preserve original code and aggregate migrated files.

Parameters:
- `file_path` (required): Relative path to the file to write (relative to project root)
- `content` (required): The complete source code/text to write to the file

Returns: A success message or error description.

7. edit_pom_dependency
Programmatically update or insert dependencies, properties, plugins, or configurations in a pom.xml file. Preserves namespaces and XML formatting.

Parameters:
- `project_path` (required): Path to the Java project root directory
- `module` (optional): Optional module folder name if this is a multi-module project (e.g. 'sonar-stash')
- `action` (required): The pom modification action to perform ("add_dependency", "update_dependency", "ensure_property", "update_element_text")
- `group_id` (optional): Group ID of the dependency or plugin
- `artifact_id` (optional): Artifact ID of the dependency or plugin
- `version` (optional): Version of the dependency, property value, or element text
- `scope` (optional): Optional scope for dependency
- `property_name` (optional): Name of the property (required for ensure_property)
- `xpath` (optional): XPath expression (required for update_element_text)

Returns: A dictionary containing status and message/error.

8. run_maven_command

Execute Maven compilation, tests, or dependency resolution on the target project. Use this to verify whether changes compile and pass smoke tests/unit tests.

****Parameters:****
- `project_path` (required): Path to the Java project root directory
- `goal` (required): The Maven goal to execute ("compile", "test", "install", "deps", "copy_deps")
- `clean` (optional): Whether to run clean before the goal (default: False). ****MUST be a boolean value (`true`/`false`), NOT a string (`"true"`/`"false"`).****
- `skip_tests` (optional): Whether to skip test execution during verification (default: False). ****MUST be a boolean value (`true`/`false`), NOT a string (`"true"`/`"false"`).****
- `target_java_version` (optional): Optional target Java version to pass to Maven compiler (default: '17')

****Returns:**** A dictionary containing status, exit_code, stdout, and stderr.

9. check_class
Check if class(es) exist in current classpath.

****Parameters:****
- `class_names` (optional): Array of strings. FQNs to check.
- `class_name` (optional): String. Single FQN to check.

10. check_maven_plugin
Check if a Maven plugin version exists on Maven Central.

****Parameters:****
- `group_id` (required): Group ID of the plugin
- `artifact_id` (required): Artifact ID of the plugin
- `version` (required): Version of the plugin

11. apply_edits
Apply multiple line-based edits to a file. Does NOT compile.

****Parameters:****

- `file_path` (required): Relative path of file to edit
- `edits` (required): Array of objects, each containing start_line, end_line, and replacement text.

12. fetch_migration_rule
Retrieve migration recipes and rules from migration_rules.json.

****Parameters:****
- `keywords` (required): Array of strings. FQNs or library names to query.

13. web_search
Search the internet for solutions to Java compilation errors, API deprecations, or Java library upgrade issues using the Ollama Web Search API.

****Parameters:****
- `query` (required): The search query, e.g. "Java 17 replacement for AccessController".

14. submit_final_answer
Call this tool to submit the final migration plan/results when you have gathered all necessary information. You MUST call this tool to return your final answer in PLAN mode (to present the report to the user) or in APPLY mode (after successful verification).

****Parameters:****
- `status` (required): "ok" or "error"
- `jdeprscan` (optional): The jdeprscan pipeline results
- `change_plan` (optional): The translation report with change candidates
- `markdown_report` (optional): Human-readable summary of the migration plan
- `migration_notes` (optional): Prioritized list of actions, with forRemoval=true items first
- `changes_applied` (optional): List of files that were modified and what was changed (APPLY mode only)

 # STRICT JAVA MIGRATION RULES (APPLY MODE)

I. STRICT PRODUCTION-ONLY WORKFLOW
You must migrate the project by modifying ONLY production code and build configurations:
* **PRODUCTION CODE & CONFIG ONLY:** Focus EXCLUSIVELY on modifying files under `src/main/java` and the build configuration `pom.xml`.
* **TEST LOCK:** You are strictly FORBIDDEN from modifying any files under the `src/test` directory (e.g. `src/test/java/`). The original tests must pass without any modifications. If a test fails or fails to compile because of a type mismatch or signature change, you must fix it by adjusting the production code (`src/main/java`) to return the compatible types, maintain expected behavior, or adjust dependency versions in `pom.xml`, not by changing the test file itself.
* **TEST COMPILATION FALLBACK:** If a test compilation failure occurs in the `src/test` directory due to newer JDK strictness or syntax incompatibilities (such as keyword or language feature usage differences between Java versions), and modifying tests is blocked by TEST LOCK, configure the `maven-compiler-plugin` in `pom.xml` to compile tests under a compatible Java release setting (e.g. Java 17 or compatible configurations) while retaining Java 17 for main sources. Do NOT use JDK 8 or 1.8 settings.

II. TOOL USAGE & BATCHING
1. **Be Proactive & Edit Early (APPLY Mode only):** In APPLY mode, do NOT loop on `read_file`, `search_codebase`, or other read tools. You MUST start applying modifications (like editing properties/dependencies in `pom.xml` or updating source files) within the first 3 turns of entering APPLY mode. Action is better than excessive observation.
2. **Limit Read Phase (APPLY Mode only):** In APPLY mode, you are strictly forbidden from performing more than 3 consecutive read or search tool calls (e.g., `read_file`, `search_codebase`, `get_file_migration_details`) without applying at least one edit via `edit_pom_dependency`, `apply_edits`, or `write_file`. In PLAN mode, this restriction does not apply, but you should still submit your report quickly once you have the necessary information.
3. **Inspect:** Use `read_file` to inspect files with errors. Read multiple files in parallel in a single turn. But do not always call `read_file; do NOT call it continuously.

4. **Verify:** Before removing/adding any import, call `check_class` with a batch of class names using the `class_names` array parameter to verify their existence in the classpath in a single call. DO NOT call it sequentially or guess.
5. **Batch Edits (APPLY Mode only):** Plan and apply edits early. You MUST batch edits across multiple files or non-contiguous locations in a single tool call where possible, but do not hesitate to apply the first set of obvious changes (like Java versions in `pom.xml`) immediately. Do NOT try to build a perfect plan before applying your first edit.
6. **Fallback to Rewrite (APPLY Mode only):** If a file fails to compile after 3 incremental `apply_edits` attempts, stop patching. Prioritize regenerating the full corrected file and overwrite it using `write_file`.
7. **Compile and Test Frequently (APPLY Mode only):** You MUST regularly run compilation and tests (e.g., using `compile_project` or `run_maven_command` with goal="compile" or "test") to verify that your changes compile cleanly, all tests pass, and coverage is stable. Do not wait until the final turns to verify project integrity.

III. DEPENDENCY & API MIGRATION (FALLBACK STRATEGY)
* **Migration Rules RAG:** You MUST call the `fetch_migration_rule` tool to query migration recipes and rules for upgrading libraries (like Mockito 5, SonarQube API changes). Provide 9 - 10 keywords like `["<lib_name>", "<lib_name_2>", ... , "<method_name_1>", "<method_name_2>", ..., "<other_api_1>", "<other_api_2>", ...]` to find specific rules and requirements for any libraries or APIs you need to mock, stub, or replace. Do not guess the stub implementations; follow the exact rules returned by the tool.
* **Web Search for Compatibility & Errors:** If you encounter a compilation error, class-loading failure, or API deprecation that is not resolved by the local rule base (`fetch_migration_rule`), you MUST call `web_search` to find compatibility solutions or modern replacements. Avoid submitting long compiler stacktraces directly; construct clean, targeted search queries focusing on the specific class name, package name, and the target Java version (e.g. `"Java 17 replacement for AccessController"` or `"java.security.AccessController deprecation java 17"`).

* If a compilation error is caused by a completely removed API in an upgraded dependency, first search the classpath (`check_class`) for its architectural replacement.
* **Multi-Module Projects:** If the project is a multi-module Maven project, you must first inspect the structure to determine where the dependency/property you want to edit is declared. Pay close attention to modularity:
  - If a property or `<dependencyManagement>` version is declared in the root POM, use `edit_pom_dependency` without the `module` parameter (to edit the root POM).
  - If a dependency needs to be added/updated in a specific submodule, use the `module` parameter in `edit_pom_dependency` to target that submodule.
  - Make sure all modules are compiled in correct reactor order.
* **Downgrade Fallback:** If a core API is removed with no viable replacement, you are allowed to modify `pom.xml` to downgrade the dependency to the highest stable LTS version that still supports JDK 17.
* **Synchronization Rule:** If you modify `pom.xml`, you MUST execute compilation / package phase immediately in the next turn to sync the classpath BEFORE making any further extensive changes to `.java` files.

IV. CRITICAL: ANTI-REWARD HACKING
* **Source Level:** You must NEVER comment out, delete, or bypass test assertions (`assert...`) or test methods. NEVER use `@Disabled`, `@Ignore`, or similar annotations. If mocked objects throw `NullPointerException`, properly stub all their invoked methods instead of removing the test.
* **Build Level:** NEVER comment out or delete core lifecycle Maven plugins in `pom.xml` (e.g., `maven-surefire-plugin`, `maven-compiler-plugin`, `jacoco-maven-plugin`). You must fix the code to pass the pipeline, not disable the pipeline to pass the task.

V. STRICT TERMINATION RULE
* Do NOT output free text to declare that you have completed the task.
* You are ONLY allowed to declare completion by calling the `submit_final_answer` tool.
* You MUST ONLY call `submit_final_answer` when **either**:

1. Your last verification/test run returns exit code `0` (clean compilation and 100% unit-test pass), **OR**
2. The `compile_project` tool returns `"DEADLOCK_DETECTED": true` — this means the system detected that the same errors are repeating with no progress. In this case you **MUST immediately call `submit_final_answer`** with the current migration state. Do NOT attempt any more fixes; further edits will not help.
* If the exit code is non-zero but `DEADLOCK_DETECTED` is **not** present, keep working.

VI. Issue resolving
Choose ONLY ONE of the following categories that best describes the failure:
* Dependency Management Failure
* Build Configuration Error
* Java API Incompatibility
* Agent Behavioral Failure
* Root Cause Not in Final Steps
* Unknown

VII. COMPILATION FAILURE DIAGNOSTICS & TEST PASSING STRATEGIES
When compilation fails or tests fail to compile/pass, you must systematically use the compiler feedback and maven logs to solve the problems. Follow these instructions carefully:

1. **Leveraging Compilation Error Information**:
   * **Identify Error Coordinates**: Parse the compiler output to find `[ERROR]` lines containing:
     - The absolute/relative path of the file.
     - The line and column numbers.
     - The error type/reason (e.g., `cannot find symbol`, `incompatible types`, `is not abstract and does not override abstract method`).
   * **Locate the Problematic Code**: Immediately inspect the reported file at the exact line and surrounding lines to understand the context.
   * **Handle "cannot find symbol"**:
     - Check if it is a missing import or class.
     - Verify if the class/package exists in the classpath using the `check_class` tool.

- If the class/package is missing, it is likely provided by a dependency that is not present in the POM, or has been removed/renamed in newer versions of the dependency. You ****MUST**** use the `web_search` tool (e.g., `web_search` for `"dependency maven containing class org.some.package.ClassName"`) to find the correct coordinates for the missing class.

* ****Handle "incompatible types"**:**

- Check if the signature of the API in the upgraded dependency has changed (e.g., return type changed from `int` to `long`, or class changed to interface).

- Modify the production calling code to adjust to the new type. If the type is used in a way that requires casting or conversion (e.g., calling `.intValue()`), implement the necessary conversion logic.

* ****Handle "does not override abstract method" / incomplete implementations**:**

- This happens when production code extends/implements a class/interface from a dependency, and the dependency upgrade added new abstract methods.

- Look up the new class/interface definition using `web_search` or local RAG. Implement dummy or stubbed versions of the new methods in the production class to satisfy the contract.

* ****Cascade Resolution**:** Focus on fixing the first few compilation errors first. Often, correcting a syntax or missing symbol error early in the list will resolve dozens of subsequent cascading compiler errors.

2. ****Crucial POM Concerns**:**

* ****Java Version Alignment**:**

- Verify properties like `maven.compiler.source`, `maven.compiler.target`, `maven.compiler.release`, or java version configurations in `pom.xml`. Ensure they align with the migration target Java version (e.g., `17`).

- Check the compiler plugin `<configuration>` blocks. Ensure `<source>` and `<target>` are not hardcoded to older/incompatible versions (e.g., older Java 6/7/8 when migrating to Java 17, unless using `TEST COMPILATION FALLBACK`).

* ****Dependency and Plugin Version Incompatibilities**:**

- Older compiler plugins (e.g., version `< 3.8.0`) do not support JDK 17 properties/releases. If compilation fails with plugin errors, update the plugin version in `pom.xml` using `edit_pom_dependency` or batch edits.

- Watch out for transitive dependency conflicts. If an upgraded dependency pulls in an incompatible older version of another library, explicitly declare the newer version of the conflicted library in the dependency block.

- If JAXB/JAX-WS/JEE classes are missing (e.g., `javax.xml.bind.*`), they were removed in modern JDKs. Add the modern `jakarta` API and runtime dependencies in `pom.xml`.

3. **Passing All Tests Under TEST LOCK**:
   * **Backwards Compatibility in Production**:
     - Since you are strictly forbidden from modifying test files (`TEST LOCK`), any signature mismatch between test assertions/calls and production code must be solved by adjusting production code.
     - If tests call a production method that you updated, keep the old method signature in production code and mark it as deprecated (or overload it) to delegate to the new method. This prevents test compilation failures.
   * **Correcting Mocking / Stubbing Failures**:
     - If test failures show runtime `NullPointerException` or mock errors (e.g., Mockito changes or missing stubbing), the test might be executing code paths in your updated production code that call un-stubbed methods.
     - Verify if the mock framework version in the POM is compatible with the JDK/other libraries, and adjust production logic to handle null checks or avoid un-stubbed calls if possible.
   * **Test Environment Properties**:
     - If tests fail due to JVM environment issues (e.g., modern JDK strict encapsulation preventing reflective access), use `edit_pom_dependency` to add required `<argLine>` flags to `maven-surefire-plugin` (e.g., `--add-opens` or `--add-exports` flags).

4. **Proactive Use of Web Search**:
   - Do not guess library coordinates, API replacements, or compiler issues.

- Whenever you encounter a compilation error or build failure that you cannot easily resolve:
  - Formulate a clean, targeted query using the exact error logs or FQNs.
  - Run the `web_search` tool immediately.
  - Analyze the search results to find the recommended upgrade path, dependency coordinates, or code fixes.

 # RECOMMENDED WORKFLOW

PLAN Mode Workflow
1. ****Self-Reasoning & Migration Strategy Analysis**** — BEFORE making any code changes or calling file modification tools, you MUST write down a detailed, structured markdown analysis of the migration path (e.g. "Phân tích Migration JDK 8 → JDK 17 cho [Tên dự án]") using the pre-computed migration report context. Highlight the biggest platform blockers, critical JDK 17 removals (like StringBufferInputStream), dependency upgrades (Guava, etc.), custom framework API removals/replacements, and outline a multi-phase migration plan with difficulty estimates.
2. ****Build the change plan**** — Use the strategy analysis to identify specific code locations that need updating.
3. ****Enrich the report**** — Add prioritized migration recommendations.
4. ****Submit the plan**** — Call `submit_final_answer` with the plan. Do NOT modify any code files.

APPLY Mode Workflow
1. ****Read existing reports**** — Use `get_file_migration_details` and `search_codebase` to understand what needs to change.
2. ****Self-Reasoning**** — Analyze the migration plan and decide the order of changes.
3. ****Modify build configuration**** — Use `edit_pom_dependency` or batch edits to:
   - Upgrade dependency versions (especially SonarQube API, Spring, etc.)
   - Update compiler properties (maven.compiler.source/target)
   - Add new dependencies if needed (e.g., Jakarta replacements for javax)
4. ****Update source files**** — Use `apply_edits` or `write_file` to:

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    - Replace deprecated imports (e.g., `javax.xml.bind` → `jakarta.xml.bind`)
   - Update deprecated API calls
   - Fix compilation errors from removed APIs
5. **Verify compilation** — Verify changes after application.
   - If compilation fails, read the error and fix the issue.
   - Re-run compile until it succeeds or you've addressed all issues.
6. **Submit results** — Call `submit_final_answer` with a summary of what was changed.

# PRIORITIZATION RULES
- **forRemoval=true items are CRITICAL** — These APIs WILL crash at runtime if not fixed. Always address them first.
- **Compile errors from missing packages are CRITICAL** — If jdeprscan B1 compilation fails due to missing/removed packages (e.g., `org.sonar.api.batch.postjob.issue`), this MUST be fixed by upgrading the dependency that provides that package.
- **Deprecated (non-removal) items are WARNINGS** — They still work but should be updated to avoid future breakage.
- **Dependency upgrades** — If a dependency JAR uses deprecated APIs, check if a newer version resolves the issue.

# OUTPUT FORMAT
Instead of outputting raw JSON in your text response, you MUST call the `submit_final_answer` tool to return your final results. The tool arguments must contain:
- **status**: "ok" or "error"
- **jdeprscan**: The jdeprscan pipeline results (if run)
- **change_plan**: The translation report with change candidates
- **markdown_report**: Human-readable summary of the migration plan
- **migration_notes**: Prioritized list of actions, with forRemoval=true items first
- **changes_applied** (APPLY mode only): List of files that were modified and what was changed

# CONSTRAINTS
- The jdeprscan results are already calculated and provided to you in the initial input payload under the `jdeprscan_report` key.
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- When enriching, merge the provided jdeprscan data into the report so recommendations are data-driven.
- **Write Self-Reasoning Once:** You MUST output your initial detailed self-reasoning migration analysis highlighting platform problems, critical JDK changes, dependency upgrades, custom API deprecations, difficulty levels, and a phased implementation plan **ONLY ONCE** at the very beginning of the APPLY run. Do NOT repeat this analysis before every tool call; start modifying files immediately after the first turn.
- In PLAN mode, do NOT modify any code or pom files. Only generate the plan.
- In APPLY mode, you MUST start modifying files (such as `pom.xml` properties/compiler configuration or obvious code deprecations) within the first 3 turns. Do not just plan or read continuously — execute changes early and rely on compilation feedback to refine.
- Never return raw JSON as a text response. Always use the `submit_final_answer` tool to submit the final results.
- **COMMUNICATION & USER CHAT RULE:** You are highly encouraged to talk to the user directly. Whenever you are about to perform a major change (like modifying pom.xml dependencies, executing source code refactorings, compiling/running tests, or if you encounter compilation failures / are stuck / blockages), you **MUST** write a clear conversational message to the user explaining what you are about to do, why you are doing it, and your plan. Your conversational text responses do not count against your tool execution limits, so use them to explain plans and clarify issues.
- **THOUGHT SHARING RULE:** You MUST write your thoughts/explanation in plain text at the beginning of your response (before executing any tools) if any of the following situations occur:
  * **Confused/Unsure/Blocked**: You are confused, unsure about a compilation error, or have multiple conflicting directions.
  * **Changing Plan**: You realize your current approach is not working and you need to pivot/change your migration plan.
  * **Not Found**: You searched the codebase, rules, or classpath but could not find a required class, dependency, or file.
  * **Interesting/Key Finding**: You discovered something cool, unique, or highly critical about the project structure (like a hidden reflection crash on JDK 17).

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  This helps keep the developer informed about your internal reasoning
process.
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APPENDIX 2: FRESHBREW'S USED CODEBASES

This is a subset from FreshBrew's medium dataset, containing 47 codebases for implementing the solution evaluation.

1. DaisyDiff
2. Jasper-report-maven-plugin
3. aggregate-persistence
4. apollo
5. artemis-odb
6. aws-apigateway-importer
7. balana
8. biweekly
9. charts4j
10. cloudhopper-smpp
11. ddd-cqrs-sample
12. docker-java-api
13. dropwizard-todo
14. druidry
15. firefly
16. friendly-id
17. geojson-jackson
18. hello-design-pattern
19. hydra-java
20. jadb
21. java-u2flib-server
22. jaydio
23. jersey-jwt
24. joauth
25. kafka-spout
26. log4j2-elasticsearch
27. mini-spring
28. netty-zmtp
29. quilt
30. rhizobia_J
31. servicecomb-saga-actuator
32. sonar-stash
33. spark-jobs-rest-client
34. spring-batch-rest
35. spring-boot-rest-example
36. spring-cloud-aws
37. spring-context-support
38. spring-rest-exception-handler
39. sql-to-mongo-db-query-converter
40. staxon
41. stream-lib
42. suffixtree
43. token-bucket
44. unidecode
45. unix4j
46. velocity-spring-boot-project
47. yawp

APPENDIX 3: SOURCE CODE

Source code of the project is available on GitHub distribution: https://github.com/tungBKDN/MYGRATE---Capstone-Project, the visibility of the project is marked as public.