CS731 Software Testing - Project Report

Team Members

Name	Roll Number
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1. Project Overview

Project Title: Two-Level Mutation Testing of Course Registration System

GitHub Link: https://github.com/py-xis/CS-731-Software-Testing-Project

2. AI Tool Acknowledgment

AI Tool: Claude Sonnet 4.5 (Thinking)

AI Assisted:
- Production code in `src/main/java/**`

Human Written:
- All test cases in `src/test/java/**`
- Test design and strategy
- Mutation testing configuration
- All assertions and test logic

-Architecture of the system.

LLM Refined:
- Documentation and reports

3. Individual Contributions

Aryan Singhal (IMT2022036):
- Modules: `repository` , `result`
- Test cases for above modules

Pranav Kulkarni (IMT2022053):
- Modules: `model` , `analytics` , `engine`
- Test cases for above modules

Implemented Together:
- Module: `core`
- Integration test cases

4. Test Design & Mutation Testing

4.1 Test Design Techniques

1. Boundary Value Analysis

2. Equivalence Partitioning

3. Decision Table Testing

4. State Transition Testing

5. Integration Testing

4.2 Mutation Testing Strategy

Unit Level:
- Target: Models, engines, repositories, analytics
- Focus: Statement-level mutations

Integration Level:
- Target: Registrar and engine orchestration
- Focus: Component interactions

4.3 Test Suite (191 Tests)

Test Class	Tests	Purpose
SeatAllocatorTest	43	Seat allocation logic
WaitlistManagerTest	38	Waitlist queue operations
PrerequisiteEngineTest	27	Prerequisite validation
RegistrarTest	21	Integration workflows
EnrollmentRepositoryTest	16	Repository CRUD
StudentRepositoryTest	12	Student data management
CourseTest	12	Course model tests
EnrollmentStatisticsTest	10	Analytics calculations
EnrollmentTest	5	Enrollment validation
CourseRepositoryTest	5	Course repository
StudentTest	2	Student model tests

4.4 Unit-Level Results (4 Operators)

Operator	Description	Killed	Total	Kill Rate
NEGATE_CONDITIONALS	Negates conditionals	101	109	93%

Operator	Description	Killed	Total	Kill Rate
MATH	Changes math operators	19	21	90%
CONDITIONALS_BOUNDARY	Changes boundaries	17	29	59%
INCREMENTS	Changes increments	1	1	100%
Total		**138**	**160**	**86%**

4.5 Integration-Level Results (6 Operators)

Operator	Description	Killed	Total	Kill Rate
PRIMITIVE_RETURNS	Returns 0	7	7	100%
NON_VOID_METHOD_CALLS	Removes method calls	159	182	87%
FALSE_RETURNS	Returns false	6	7	86%
NULL_RETURNS	Returns null	21	25	84%
TRUE_RETURNS	Returns true	18	26	69%
EMPTY_RETURNS	Returns empty	2	5	40%
Total		**213**	**252**	**84%**

Overall Mutation Score: 85.19%

5. Tools Used

JUnit 5:
- Unit testing framework
- Assertions

Maven:
- Build automation
- Dependency management

PITest 1.14.2:
- Mutation testing
- Report generation

6. How to Run

Prerequisites:

```
java -version  # Verify Java 11+mvn -version   # Verify Maven 3.8+
```

Run All Tests:

```
mvn clean test
```

Unit Mutation Testing:

```
mvn org.pitest:pitest-maven:mutationCoverage@unit-mutation-testing
```

Report: `target/pit-reports/unit/index.html`

Integration Mutation Testing:

```
mvn org.pitest:pitest-maven:mutationCoverage@integration-mutation-testing
```

Report: `target/pit-reports/integration/index.html`

7. Test Execution Screenshots

7.1 All Tests Passing

```
[INFO] -------------------------------------------------------
[INFO]  T E S T S
[INFO] -------------------------------------------------------
[INFO] Running edu.courseregistration.repository.EnrollmentRepositoryTest
[INFO] Tests run: 16, Failures: 0, Errors: 0, Skipped: 0, Time elapsed: 0.037 s -- in edu.courseregistration.repository.EnrollmentRepositoryTest
[INFO] Running edu.courseregistration.repository.CourseRepositoryTest
[INFO] Tests run: 5, Failures: 0, Errors: 0, Skipped: 0, Time elapsed: 0.002 s -- in edu.courseregistration.repository.CourseRepositoryTest
[INFO] Running edu.courseregistration.repository.StudentRepositoryTest
[INFO] Tests run: 12, Failures: 0, Errors: 0, Skipped: 0, Time elapsed: 0.007 s -- in edu.courseregistration.repository.StudentRepositoryTest
[INFO] Running edu.courseregistration.core.RegistrarTest
[INFO] Tests run: 21, Failures: 0, Errors: 0, Skipped: 0, Time elapsed: 0.013 s -- in edu.courseregistration.core.RegistrarTest
[INFO] Running edu.courseregistration.model.StudentTest
[INFO] Tests run: 2, Failures: 0, Errors: 0, Skipped: 0, Time elapsed: 0 s -- in edu.courseregistration.model.StudentTest
[INFO] Running edu.courseregistration.model.EnrollmentTest
[INFO] Tests run: 5, Failures: 0, Errors: 0, Skipped: 0, Time elapsed: 0.006 s -- in edu.courseregistration.model.EnrollmentTest
[INFO] Running edu.courseregistration.model.CourseTest
[INFO] Tests run: 12, Failures: 0, Errors: 0, Skipped: 0, Time elapsed: 0.003 s -- in edu.courseregistration.model.CourseTest
[INFO] Running edu.courseregistration.engine.SeatAllocatorTest
[INFO] Tests run: 43, Failures: 0, Errors: 0, Skipped: 0, Time elapsed: 0.013 s -- in edu.courseregistration.engine.SeatAllocatorTest
[INFO] Running edu.courseregistration.engine.PrerequisiteEngineTest
[INFO] Tests run: 27, Failures: 0, Errors: 0, Skipped: 0, Time elapsed: 0.010 s -- in edu.courseregistration.engine.PrerequisiteEngineTest
[INFO] Running edu.courseregistration.engine.WaitlistManagerTest
[INFO] Tests run: 38, Failures: 0, Errors: 0, Skipped: 0, Time elapsed: 0.010 s -- in edu.courseregistration.engine.WaitlistManagerTest
[INFO] Running edu.courseregistration.analytics.EnrollmentStatisticsTest
[INFO] Tests run: 10, Failures: 0, Errors: 0, Skipped: 0, Time elapsed: 0.005 s -- in edu.courseregistration.analytics.EnrollmentStatisticsTest
[INFO]
[INFO] Results:
[INFO]
[INFO] Tests run: 191, Failures: 0, Errors: 0, Skipped: 0
[INFO]
[INFO] ------------------------------------------------------------------------
[INFO] BUILD SUCCESS
[INFO] ------------------------------------------------------------------------
[INFO] Total time:  1.277 s
[INFO] Finished at: 2025-11-25T23:55:51+05:30
[INFO] ------------------------------------------------------------------------
```

7.2 Unit-Level Mutation Results

```
=============================================================================
— Mutators
=============================================================================
> org.pitest.mutationtest.engine.gregor.mutators.ConditionalsBoundaryMutator
>> Generated 29 Killed 17 (59%)
> KILLED 17 SURVIVED 11 TIMED_OUT 0 NON_VIABLE 0
> MEMORY_ERROR 0 NOT_STARTED 0 STARTED 0 RUN_ERROR 0
> NO_COVERAGE 1
-----------------------------------------------------------------------------
> org.pitest.mutationtest.engine.gregor.mutators.IncrementsMutator
>> Generated 1 Killed 1 (100%)
> KILLED 1 SURVIVED 0 TIMED_OUT 0 NON_VIABLE 0
> MEMORY_ERROR 0 NOT_STARTED 0 STARTED 0 RUN_ERROR 0
> NO_COVERAGE 0
-----------------------------------------------------------------------------
> org.pitest.mutationtest.engine.gregor.mutators.MathMutator
>> Generated 21 Killed 19 (90%)
> KILLED 19 SURVIVED 0 TIMED_OUT 0 NON_VIABLE 0
> MEMORY_ERROR 0 NOT_STARTED 0 STARTED 0 RUN_ERROR 0
> NO_COVERAGE 2
-----------------------------------------------------------------------------
> org.pitest.mutationtest.engine.gregor.mutators.NegateConditionalsMutator
>> Generated 109 Killed 101 (93%)
> KILLED 101 SURVIVED 1 TIMED_OUT 0 NON_VIABLE 0
> MEMORY_ERROR 0 NOT_STARTED 0 STARTED 0 RUN_ERROR 0
> NO_COVERAGE 7
-----------------------------------------------------------------------------
```

```
=============================================================================
— Timings
=============================================================================
> pre-scan for mutations : < 1 second
> scan classpath : < 1 second
> coverage and dependency analysis : < 1 second
> build mutation tests : < 1 second
> run mutation analysis : 4 seconds
-----------------------------------------------------------------------------
> Total  : 4 seconds
-----------------------------------------------------------------------------
```

```
=============================================================================
— Statistics
=============================================================================
>> Line Coverage (for mutated classes only): 391/494 (79%)
>> Generated 160 mutations Killed 138 (86%)
>> Mutations with no coverage 10. Test strength 92%
>> Ran 225 tests (1.41 tests per mutation)
Enhanced functionality available at https://www.arcmutate.com/
[INFO] -----------------------------------------------------------------------
[INFO] BUILD SUCCESS
[INFO] -----------------------------------------------------------------------
[INFO] Total time:  5.235 s
[INFO] Finished at: 2025-11-25T23:56:02+05:30
[INFO] -----------------------------------------------------------------------
```

7.3 Integration-Level Mutation Results

```
================================================================================
— Mutators
================================================================================
> org.pitest.mutationtest.engine.gregor.mutators.returns.PrimitiveReturnsMutator
>> Generated 7 Killed 7 (100%)
> KILLED 7 SURVIVED 0 TIMED_OUT 0 NON_VIABLE 0
> MEMORY_ERROR 0 NOT_STARTED 0 STARTED 0 RUN_ERROR 0
> NO_COVERAGE 0
--------------------------------------------------------------------------------
> org.pitest.mutationtest.engine.gregor.mutators.returns.BooleanTrueReturnValsMutator
>> Generated 26 Killed 18 (69%)
> KILLED 18 SURVIVED 1 TIMED_OUT 0 NON_VIABLE 0
> MEMORY_ERROR 0 NOT_STARTED 0 STARTED 0 RUN_ERROR 0
> NO_COVERAGE 7
--------------------------------------------------------------------------------
> org.pitest.mutationtest.engine.gregor.mutators.returns.NullReturnValsMutator
>> Generated 25 Killed 21 (84%)
> KILLED 21 SURVIVED 0 TIMED_OUT 0 NON_VIABLE 0
> MEMORY_ERROR 0 NOT_STARTED 0 STARTED 0 RUN_ERROR 0
> NO_COVERAGE 4
--------------------------------------------------------------------------------
> org.pitest.mutationtest.engine.gregor.mutators.returns.BooleanFalseReturnValsMutator
>> Generated 7 Killed 6 (86%)
> KILLED 6 SURVIVED 1 TIMED_OUT 0 NON_VIABLE 0
> MEMORY_ERROR 0 NOT_STARTED 0 STARTED 0 RUN_ERROR 0
> NO_COVERAGE 0
--------------------------------------------------------------------------------
> org.pitest.mutationtest.engine.gregor.mutators.returns.EmptyObjectReturnValsMutator
>> Generated 5 Killed 2 (40%)
> KILLED 2 SURVIVED 1 TIMED_OUT 0 NON_VIABLE 0
> MEMORY_ERROR 0 NOT_STARTED 0 STARTED 0 RUN_ERROR 0
> NO_COVERAGE 2
--------------------------------------------------------------------------------
> org.pitest.mutationtest.engine.gregor.mutators.NonVoidMethodCallMutator
>> Generated 182 Killed 159 (87%)
> KILLED 159 SURVIVED 16 TIMED_OUT 0 NON_VIABLE 0
> MEMORY_ERROR 0 NOT_STARTED 0 STARTED 0 RUN_ERROR 0
> NO_COVERAGE 7
--------------------------------------------------------------------------------
```

```
================================================================================
— Timings
================================================================================
> pre—scan for mutations : < 1 second
> scan classpath : < 1 second
> coverage and dependency analysis : < 1 second
> build mutation tests : < 1 second
> run mutation analysis : 3 seconds
--------------------------------------------------------------------------------
> Total  : 3 seconds
................................................................................
```

```
================================================================================
- Statistics
================================================================================
>> Line Coverage (for mutated classes only): 220/234 (94%)
>> Generated 252 mutations Killed 213 (85%)
>> Mutations with no coverage 20. Test strength 92%
>> Ran 404 tests (1.6 tests per mutation)
Enhanced functionality available at https://www.arcmutate.com/
[INFO] ------------------------------------------------------------------------
[INFO] BUILD SUCCESS
[INFO] ------------------------------------------------------------------------
[INFO] Total time:  4.345 s
[INFO] Finished at: 2025-11-25T23:56:12+05:30
[INFO] ------------------------------------------------------------------------
```
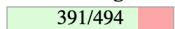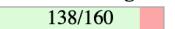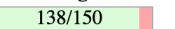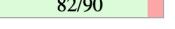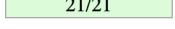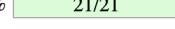
7.4 PIT Reports

Pit Test Coverage Report

Project Summary

Number of Classes	Line Coverage		Mutation Coverage		Test Strength	
10	79%	391/494	86%	138/160	92%	138/150

Breakdown by Package

Name	Number of Classes	Line Coverage		Mutation Coverage		Test Strength	
edu.courseregistration.analytics	1	86%	83/96	74%	28/38	74%	28/38
edu.courseregistration.engine	3	99%	126/127	97%	64/66	97%	64/66
edu.courseregistration.model	3	55%	100/181	71%	25/35	100%	25/25
edu.courseregistration.repository	3	91%	82/90	100%	21/21	100%	21/21
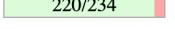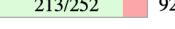
Report generated by PIT 1.15.3
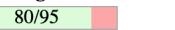
Enhanced functionality available at arcmutate.com
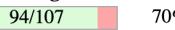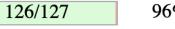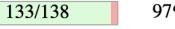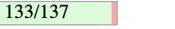
Unit Testing PIT Report

Pit Test Coverage Report

Project Summary

Number of Classes	Line Coverage		Mutation Coverage		Test Strength	
4	94%	220/234	85%	213/252	92%	213/232

Breakdown by Package

Name	Number of Classes	Line Coverage		Mutation Coverage		Test Strength	
edu.courseregistration.core	1	88%	94/107	70%	80/114	84%	80/95
edu.courseregistration.engine	3	99%	126/127	96%	133/138	97%	133/137

Report generated by PIT 1.15.3

Enhanced functionality available at arcmutate.com

Integration Testing PIT Report

8. Repository Structure

```
Project/
├── pom.xml              # Maven config
├── README.md              # How to run
├── Report.pdf            # PDF Format of the README.md
└── src/
    ├── main/java/edu/courseregistration/
    │   ├── model/         # Domain models
    │   ├── engine/        # Business logic
    │   ├── repository/     # Data access
    │   ├── core/          # Integration
    │   ├── result/        # Result objects
    │   └── analytics/      # Analytics
    └── test/java/edu/courseregistration/
        ├── model/         # Model tests
        ├── engine/        # Engine tests
        ├── repository/     # Repository tests
        ├── core/          # Integration tests
        └── analytics/      # Analytics tests
```

9. Conclusion

This project demonstrates two-level mutation testing on a Course Registration System.

Results:
- Unit-level: 86% kill rate
- Integration-level: 84% kill rate
- Overall: 85.19% kill rate

10. References

1. PIT Mutation Testing: http://pitest.org/

2. JUnit 5: https://junit.org/junit5/

3. Apache Maven: https://maven.apache.org/