MuClipse: Mutation Testing for Eclipse

A comprehensive report of accomplishments
during Independent Study Research with Dr. Laurie Williams

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1/13/2007

http://muclipse.sourceforge.net

Background

The Mutation Process

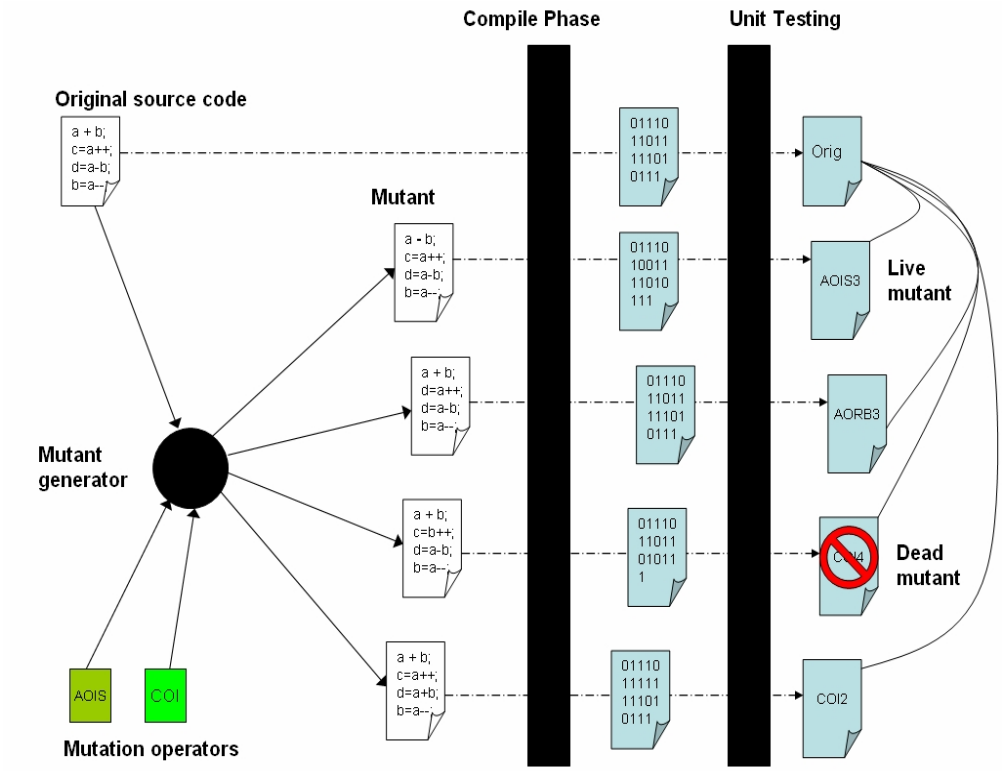


Figure: The Mutation Testing Process

One iteration of the mutation process involves the creation of mutants, executing unit tests with mutants in the place of source code, and comparing the results of the mutants output to the results of the original (see above Figure).

Mutants are modifications of source code that have been modified by mutation operators. The primary concept behind mutation testing is that modifying the source code of a given unit (or mutating it) should cause the test that operates on that unit to fail. If a class is mutated, it should cause the test cases to fail or produce different results than the original (except in the case of a false positive).

If the mutation procedure reveals a true positive, the developer then knows that there is a weakness in his or her test code: if changing the code does not produce a test failure, the test is missing something. The developer studies how the mutant is different from the original, and tries to write a test that will catch this possible error, thus beginning a second iteration of the process. In this way, the mutation testing procedure helps the developer to create strong test sets.

MuJava

MuJava, by Yu Seung Ma, Dr. Yong Rae Kwon and Dr. Jeff Offut, is a Mutation System for Java files. Using OpenJava, MuJava provides both a user interface and an API for performing mutation on existing Java classes. After performing either method-level or class-level mutations on specified Java classes, MuJava runs testcases on the original classes and again on the mutants and compares the result, thereby implementing the Mutation Process described above.

Eclipse

The Eclipse development environment provides many project management and development interfaces that greatly enhance designing and implementing a Java project. Specifically, it provides an API which makes performing mutation testing easier. For more information, see the next section.
(MuJava + Eclipse)

MuClipse

MuClipse is an Eclipse Plugin which provides a bridge between the existing MuJava API and the Eclipse Workbench.

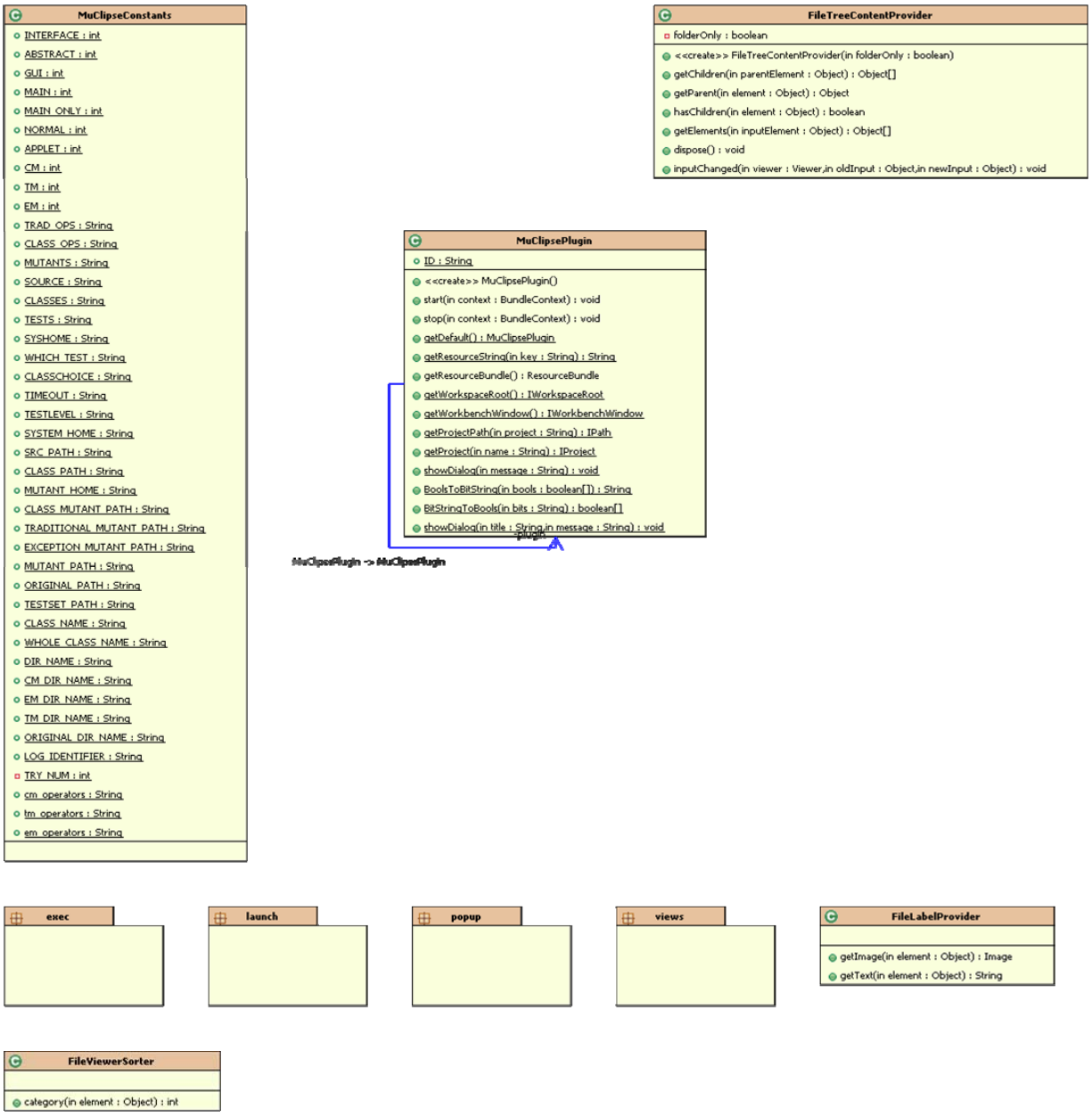
MuClipse is a reincarnation of the MuJava tool in the form of an Eclipse plug in. The mutation process requires a large amount of meta-language manipulation. Since mutation operators act on the source code, the produced mutant has to then be compiled before it can be run against the test cases. In addition, mutation testing requires that the mutant's source code not be on the Java classpath if you are attempting to "kill" it. Both of these steps require very specific Java runtime settings, which are handled by the configurations that come with the MuClipse installation.

MuClipse provides advances for the MuJava system in the areas of usability and compatibility. The following improvements help explain its motivation:

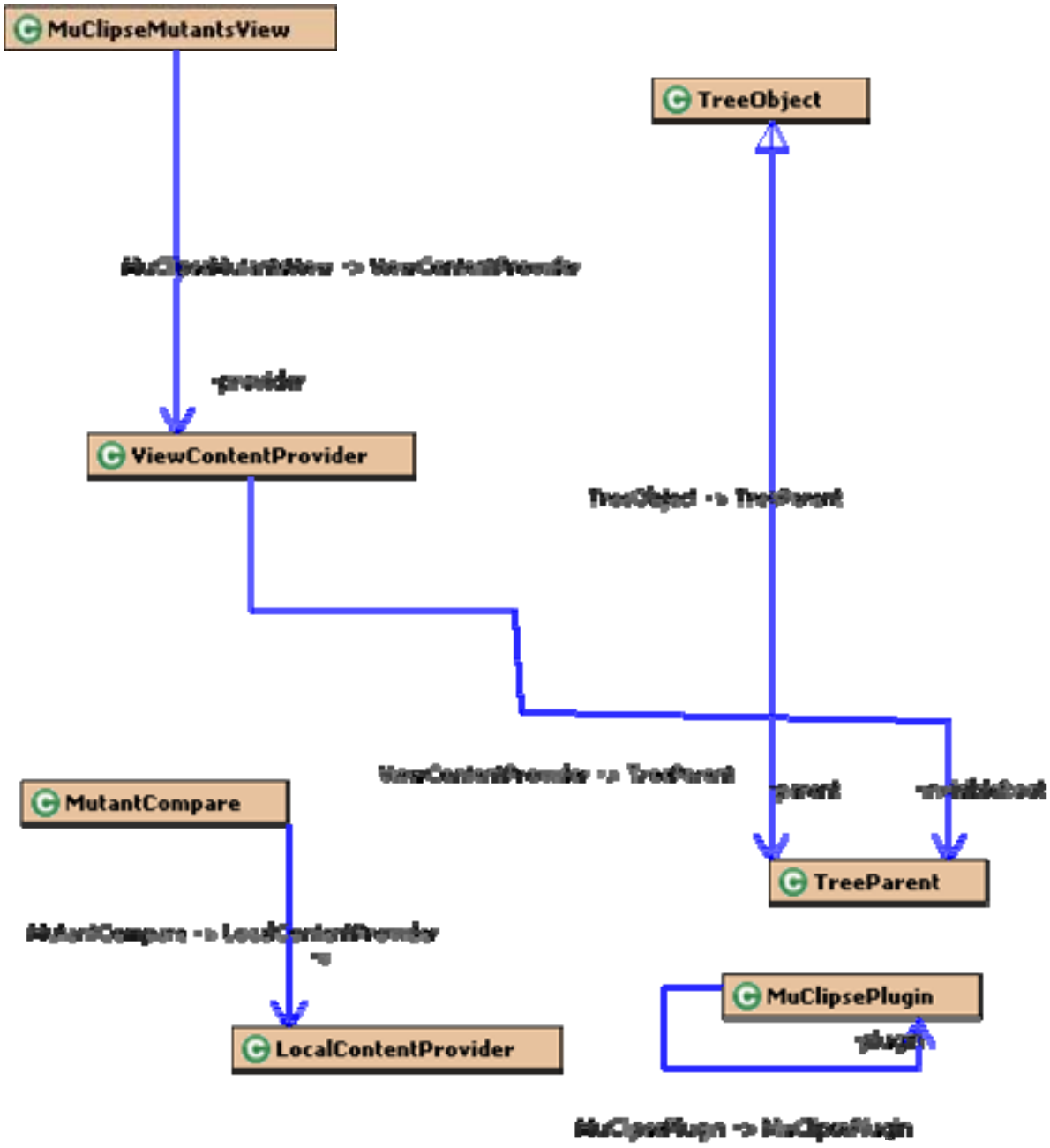
- Classpath Management
- Directory Structure Configuration
- Runtime Configuration
- Integrated GUI-based Results

Design

The Top Package



Relevant Interclass View



Use

Setting up your project

extendedOJ

Neither the process of Generating Mutants nor the process of Running Test Cases will function correctly if extendedOJ is not on your buildpath. To put it on your buildpath, follow these steps:

1. Download extendedOJ from the link above and save it into a directory within your project's root (we recommend `/lib`).
2. Open Eclipse and open the workspace with your project in it. Right click on the extendedOJ file within Eclipse and go to Build Path -> Add to Build Path. As shown below:

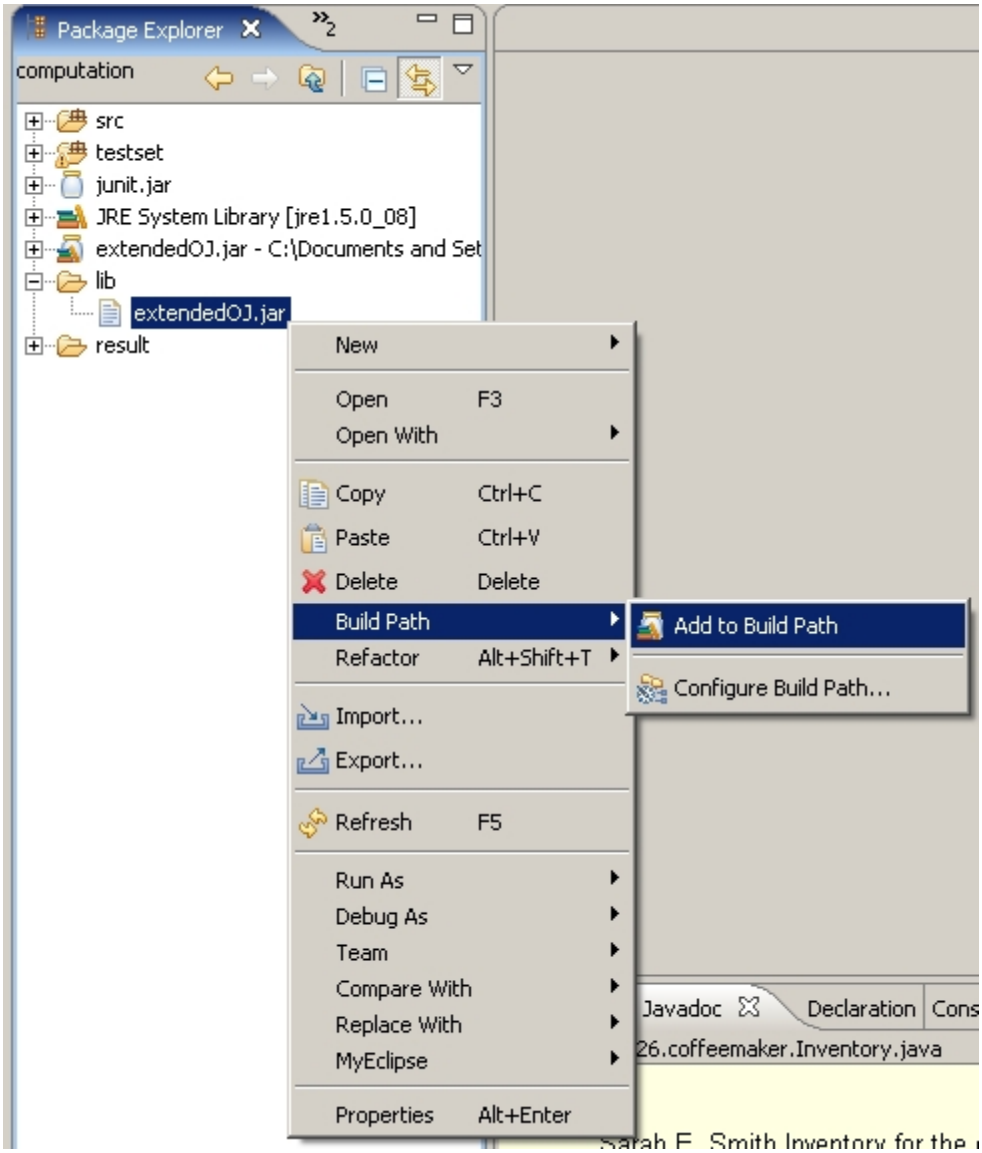


Figure 1: Adding extendedOJ to the buildpath

3. Your project should rebuild.

Folder Structure

The following requirements for the directory of your structure must also be implemented to use MuJava.

- You will need a folder within your project's root directory called `result`. No other name will work with this version of MuClipse.
- Your source code and unit tests must be in two seperate source folders.
- Your unit tests must compile to their source folder. To set this up, right click your source folder containing unit tests, go to Build Path -> Configure output folder, select the radio button "Specific output folder" and type in the same path as the source folder.

jUnit

IMPORTANT: If you are going to be running jUnit test cases to perform your mutation testing, their `setUp()` method needs to have the declaration `public` (its default is `protected`).

Generating Mutants

To generate mutants you will use the "MuClipse: Mutants" runtime configuration. Follow these steps to open and prepare your configuration:

- **IMPORTANT:** Click on the project you are working with.
- Go to the arrow to the left of run and select "Run ..." as shown below.

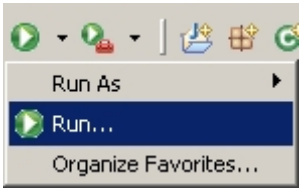


Figure 2: Opening the runtime configuration

- The Eclipse runtime configuration dialog box will appear. Select "MuClipse: Mutants" and click "New".

The Directories Tab

The following is an explanation of the fields on the "Directories" tab as shown below.

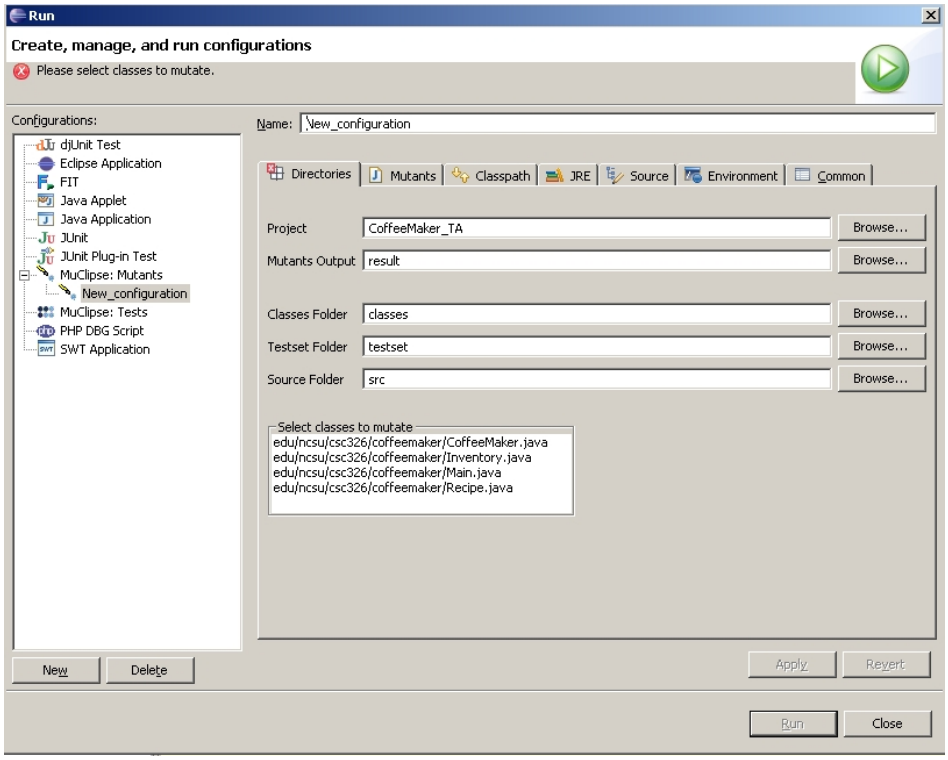


Figure 3: Directories

- `Project`: The selected project.
- `Mutants Output`: Where the mutation results will go--should almost always be "result"
- `Classes Folder`: The **root** of where your compiled Java binaries are (usually "bin")
- `Testset Folder`: The **root** of where your test case source files are
- `Source Folder`: The **root** of where your source code files are

- After you have correctly pointed all the folder fields to the correct locations, select a class (or many) to mutate.
- You are not done: see the mutants tab for more information.

The Mutants Tab

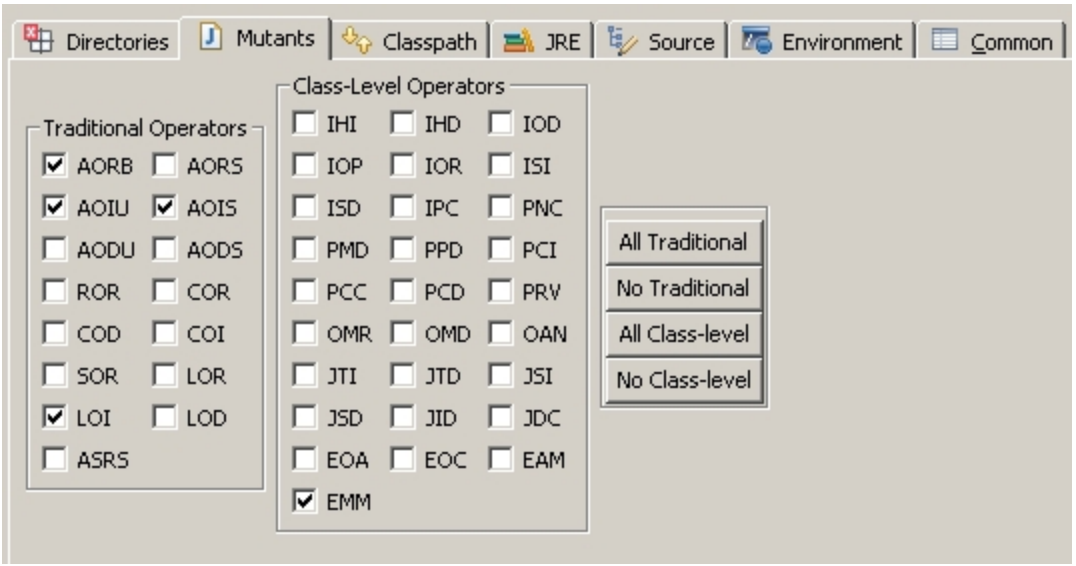


Figure 4: Mutants

Select the mutation operators you would like to use. We recommend not using all of them, as the execution time for the running test cases phase increases exponentially for each mutation operator you use. For more information on what each operator does, see the MuJava homepage.

Execution

MuClipse will now create the mutants you have specified. Some operators will not produce any mutants. If they do not, try different operators. The console will show "Mutants have been created!" when the process is complete. If you would like to see your mutants without any test case information, proceed to the section "Viewing Results" below.

Running Test Cases

To generate mutants you will use the "MuClipse: Tests" runtime configuration. Follow these steps to open and prepare your configuration:

- **IMPORTANT:** Click on the project you are working with.
- Go to the arrow to the left of run and select "Run ..." as shown below.

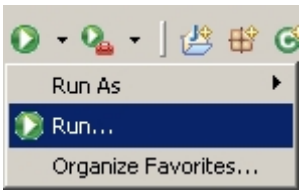


Figure 5: Opening the runtime configuration

- The Eclipse runtime configuration dialog box will appear. Select "MuClipse: Tests" and click "New".

The Directories Tab

The following is an explanation of the fields on the "Directories" tab as shown below.

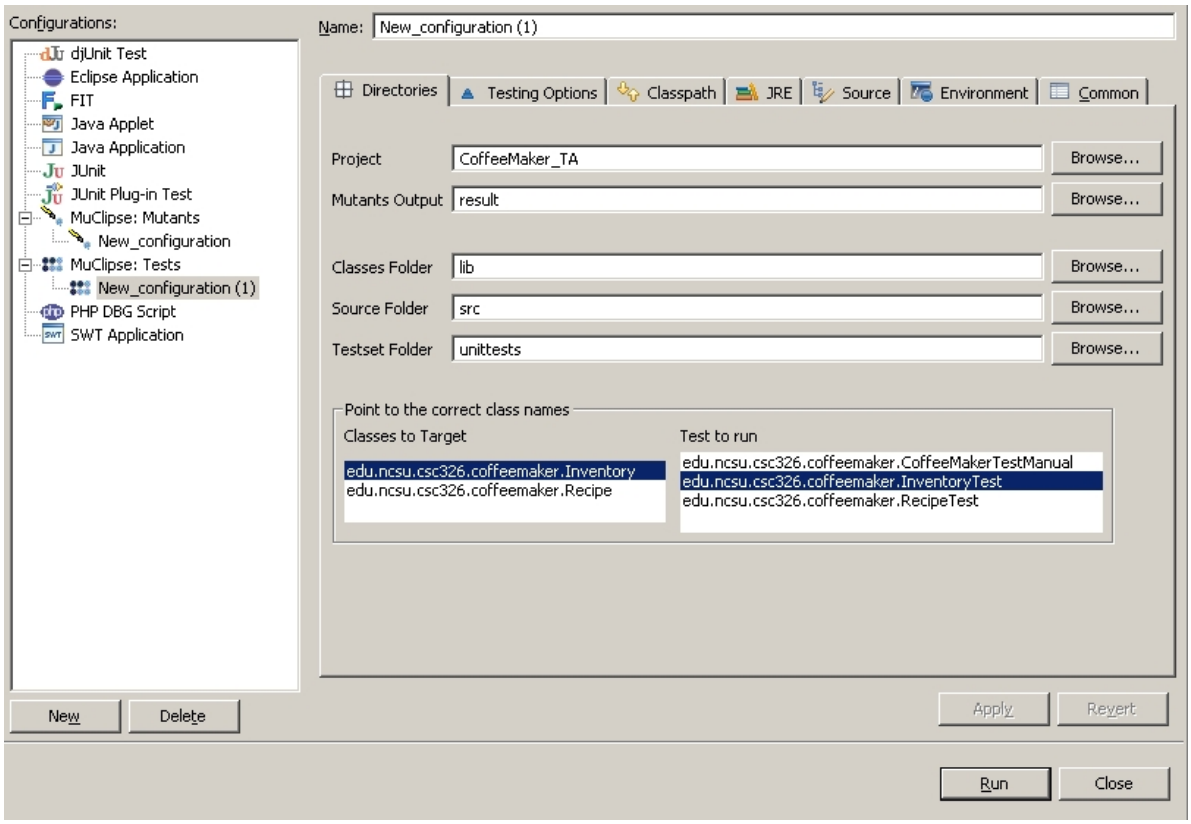


Figure 6: Directories

- `Project`: The selected project.
- `Mutants Output`: Where the mutation results will go--should almost always be "result"
- `Classes Folder`: The **root** of where your compiled Java binaries are (usually "bin")

- `Testset Folder`: The **root** of where your test case source files are
- `Source Folder`: The **root** of where your source code files are

- After you have correctly pointed all the folder fields to the correct locations, select a unit test class to run.
- Then select the class (or classes) which are targeted by this test case.
- You are not done: see the mutants tab for more information.

The Testing Options Tab

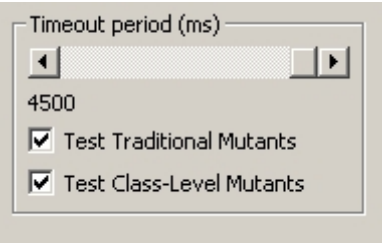


Figure 7: Testing Options

The testing options tab allows you to specify the following options:

- The Timeout Period: This is the amount of time each testcase is given to run. If a testcase causes an infinite loop, MuClipse kills that thread and counts that as a failure. If a lot of testcases are failing, increase this value. If execution is taking too long, decrease this value.
- Test Traditional/Class-Level Mutants: These are two different types of operators. Do not test an operator type which you did not create mutants for or which did not generate any mutants.

Execution

When you have finished specifying your options, click "Run." The console window will display output indicating the test results. The last thing in the output window should be your mutation score and killed/live numbers. When execution is complete, the console will display these statistics and the string "Writing to file..."

Viewing Results

- To view your mutants, right click on the `result` folder and go to MuClipse -> View Mutants and Results.
- Each root node in the view of the tree that will appear is a class, underneath which are the Class-Level and Method-Level mutant nodes. The Method-Level mutants are seperated by method name.
- The node names correspond to the name of the mutation operator and this instance of its mutation. If you have run test results, the name will show "killed" or "alive" depending on its status.
- To see how a particular mutant compares to its original, double click one of the nodes.

MuClipse Requirements Specification

v0.4
12/6/2006

Project Team:
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1. Introduction

There are already several open source Java mutation (JMutation) systems. MuJava and Jester are two examples of such tools. MuJava, in particular, provides both class-level and method-level mutation operators and provides a "mutant score" which shows the percentage of total mutants were killed by a user's test set.

Jester and MuJava both have a high initial setup overhead and a configuration overhead for each project with which they are to be used. The functionality for performing Mutation Testing already exist in the open source MuJava libraries and therefore can be cleanly transformed into an Eclipse Application. MuClipse, as its name suggests, is a JMutation system which will function as an Eclipse plugin. This unique constraint will provide the system with direct access to the directory structure and environment variables, which it can pass on to the developer as an easy-to-setup Eclipse runtime configuration.

The requirements below are categorized by Functional and Non-functional but also by subcategory. They are prioritized using the following system:

#	Declaration of Meaning
1	If this requirement is not implemented in the application, the application is not complete.
2	This requirement is important, but the application can be usable without it.
3	This requirement is not important, but would improve upon the usability or appearance of the application.

2. Functional Requirements

2.1 Usability.

2.1.1

The system shall allow the developer to easily see which mutants were killed, which remain alive and the mutation score for the last execution of test cases.

Description: The results are the main point of performing mutation testing—if the developer is not able to see which mutants are not caught by the existing test set, then there is no way to improve the test set to kill the additional mutants.

Origin: The MuJava Tool.

Priority: 1

2.1.2

The system shall allow the developer to specify the location where mutants generated are to be placed, and where original source code, test cases and compiled Java classes are located.

Description: The original tool requires a very specific directory structure which it uses to look for mutants, source code, test cases and compiled Java classes (binary objects). The system should be able to take input before running which could override this structure if the developer so desires.

Origin: Ben Smith.

Priority: 1

2.2 Generating Mutants.

2.2.1

The system shall be able to generate, store and compile mutated classes.

Description: Given a set of mutation operators, the system shall perform the mutations on the various source code selections and save the results into a designated location. After it has finished, the system will compile these classes for later use.

Origin: The MuJava Tool.

Priority: 1

2.2.2

The system shall be able to perform the mutation operations the developer selects.

Description: The developer will be presented with a list of mutants that the MuJava libraries distribute. From the graphical interface, the developer can specify which mutation operators should be used with this pass of generation.

Origin: The MuJava Tool.

Priority: 3

2.2.3

The system shall mutate the source code the developer chooses.

Description: Since the mutation process can be quite time- and processor-intensive, the developer may only want to expose weaknesses for or focus on a single class. The system shall allow this option.

Origin: The MuJava Tool.

Priority: 3

2.3 Test Sets.

2.3.1

The system shall run the set of tests the developer specifies, tabulate the results of those tests and compare them with the results of each mutant.

Description: The developer will be presented with a list of choices for tests which can be run against the mutants that have been generated.

Origin: The MuJava Tool.

Priority: 2

2.3.2

The system shall be able to run tests selectively on a declared type of mutants.

Description: The developer will be presented with a class of mutant (class-level, method-level or both) choice on which to run test cases.

Origin: The MuJava Tool.

Priority: 3

2.3.3

The system shall run both MuJava tests and jUnit TestCases.

Description: These two test types (see glossary for more information) have different return types and are in fact different Object types. The system must be able to collate the test results for both.

Origin: Laurie Williams

Priority: 3

3. Nonfunctional Requirements

3.1.1

The system shall display both a textual output of its actions and an overall progress indication during its execution.

Description: Generating mutants and collating results for the various test cases takes a long time in mutation testing. The developer needs a progress indication more than the textual output provided by the tool. These textual indications do not give an endpoint that is clear enough.

Origin: Ben Smith.

Priority: 3

4. Constraints

4.1

The process of generating mutants and running test cases on those mutants shall be accessible in the form of an Eclipse Runtime Configuration.

4.2

The killed and live mutant results shall be available in the form of an Eclipse View.

4. Requirements Traceability Matrix

Requirement	->	2.1.1	2.1.2	2.2.1	2.2.2	2.2.3	2.3.1	2.3.2	2.3.3
	2.1.1			**X**			**X**		
	2.1.2								
	2.2.1								
	2.2.2			**X**					
	2.2.3			**X**					
	2.3.1			**X**					
	2.3.2						**X**		
	2.3.3						**X**		

5. Development and Target Platforms

The MuClipse tool shall be developed to be a plugin which will be available for Eclipse v3.1.x, which is a multi-platform Integrated Development Environment.

6. Glossary

- class-level: a newer type of mutation which modifies method and class keywords to change scope, persistence and other object-oriented attributes
- Eclipse runtime configuration: a saved template of a runtime configuration for multiple repeated runs.
- jUnit TestCases: test objects which are of type junit.framework.TestCase. The structure is to have all methods with no return type and call static methods from the superclass to evaluate your results. If the results do not hold true, an exception of type junit.framework.AssertionFailedError is thrown.
- method-level: see traditional.
- MuJava tests: test objects created for use with the original MuJava libraries. The structure is to have a simple Java object with varying methods (which have various return types) starting with the word “test”.
- mutant: a copy of the source code under test after it has undergone modification (mutations) by the mutation operators
    - live: the mutant did not cause its corresponding test case to fail
    - killed: the mutant caused its corresponding test case to fail
- mutation: the process of modifying segments of the original source
- mutation operator: the specifications for how a given class of mutation is going to be performed—implemented using a Reader and Writer for this operator
- mutation score: a percentage, given by (mutants killed) / (total mutants for this run), which acts as a metric for how effective the unit test cases are at detecting errors in the source code.
- mutation system: a program or tool which allows for both generating mutants and running a set of test cases on those mutants to compare with the original results
- runtime configuration: a set of objects on the Java classpath, parameters passed to the Java runtime environment, and other environment settings specified to allow a desired program (or tool) to run correctly
- traditional: the original mutation type, which consists of making changes to only source code which exists within a method body.
- test set: a group of Java classes which execute tests on their corresponding source classes

7. Document Revision History

Version	0.4
Name(s)	Ben Smith
Date	10/19/2006
Change Description	Dropped requirement of single-run execution

Version	0.3
Name(s)	Ben Smith
Date	10/19/2006
Change Description	Dropped requirement of single-run execution

Version	0.2
Name(s)	Ben Smith
Date	10/19/2006
Change Description	Moved many non-functional requirements into the functional section. Dropped implementation specifications that were not requirements. Added constraints section.

Version	0.1
Name(s)	Ben Smith
Date	10/6/2006
Change Description	Initial Draft