Software Testing

Y1481702

April 10, 2018

Contents

1 Test Plan

1.1 Introduction

MASON is a software library for creating agent-based simulations in Java. The software fits into the category of shrinkwrap meaning it might be in use in a wide range of real-world production environments. The software is freely-available and open-source, which is a special case of shrinkwrap software. A common trait of open-source software is that tasks 'that are not considered "fun" often don't get done'.[1] For MASON in particular, it is likely that the software has not been thoroughly tested as there is no trace of any automated testing, either on the MASON website, or its GitHub repository.

1.1.1 Tools

The IntelliJ IDE was used to explore the code and develop automated tests. This IDE gives powerful features, including plugins for generating code metrics and displaying coverage of unit testing. Specifically, the MetricsReloaded plugin[2] has been used for generating the statistics in Fig. 3.

JUnit has been used to create automated unit testing for the software. Git version control has been used to manage the code for these JUnit tests. For a long term project, this would be particularly advantageous as any automated tests could be updated and versioned alongside any future code changes.

1.2 Test Coverage

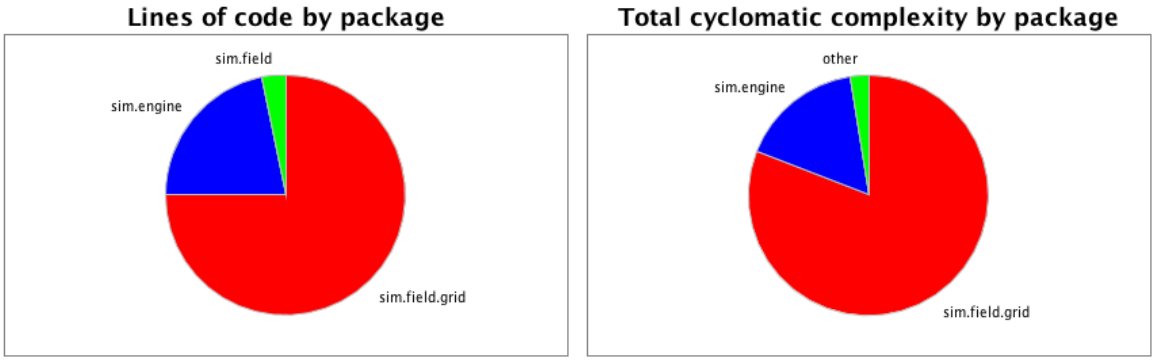
1.2.1 System Overview

In order to design appropriate test cases an understanding of all levels of the system was needed. As resources here are significantly limited, with only 8 testcases are allowed, it will be necessary to ensure they are used in the most effective way. As stated in the project brief, the testing only needs to cover the following packages, but not their subpackages:

- `sim.engine` is responsible for the core simulation management, including the agent scheduling.
- `sim.field` provides abstract classes for the representations of space in MASON simulation models, with subpackages managing specific instances of these.
- `sim.field.grid` provides various 2D and 3D grid representations of simulation space.

Fig. 1a shows the proportional sizes of each of these three modules, while Fig. 6 shows their code components.

It has been shown across software projects that some modules of code may be significantly more error prone than others. The Pareto principle is said to hold with software bugs, with



(a) Lines of Code (b) Cyclomatic Complexity

Figure 1: Charts showing various metrics of MASON

80% of software bugs being found within 20% of the code[3, pp. 124]. We can use a variety of metrics about our software to predict which parts of the code that these bugs may be hiding in[4].

High cyclomatic complexity (Fig. 1b/Fig. 3c) can be a good indicator of the most bug-ridden sections of applications. The causality here can be easily understood: complexity creates confusion which results in developers misunderstanding the software they are trying to build. This misunderstanding can provoke a large number of bugs in the code. The graphs show that `sim.field.grid` has a slightly higher share of the code's complexity than lines of code, this should be investigated in further detail.

Fig. 3d shows how the packages in the test scope interact with other packages in the system. In particular, `sim.engine` is relied on by a large number of packages. Code coverage has provided a good understanding of which parts of the [code] are regularly used while running the software. How often different source files have changes is also a particularly useful metric. Files which are subject to frequent change have had more opportunity to develop additional bugs.

Producing the right metrics to help test the application have been particularly difficult in this case. No real history of previous bug tracking GitHub commits are all credited to *eclab* rather than individual developers

1.2.2 Testing Goals

There are a number of goals we could define for our testing, such as finding the maximum number of bugs or complying with regulator set demands. The given requirement here is to verify, with a limited number of resources, that the software is dependable. In general, it's

better to test with the aim of showing a product fails, if we cannot do so then the product is reliable enough[5, pp. 20]. As such, the main requirement for our testing is to find any significant undiscovered bugs in commonly used code.
Due to limited resources, the tests will aim to cover the parts of the software which are likely to be used more often by the target users. MASON is bundled with some demo simulations that give example usages for the library. Running these simulations with code coverage detection turned on has given a good overview of which parts of the code are used regularly (Fig. 7). Core simulation code that is used routinely by all simulations regardless of their customisations should be tested the most rigourously. Both the documentation and code coverage checks indicate that this type of code can be found within `sim.engine`.

1.2.3 Expected Behaviour

The system behaviour has been tested against the inferred requirements of the client, a private biological research institute.
The expected behaviour of the software has been determined using the extensive MASON documentation[6], first-party example implementations as well as a number of open-source examples[7].

1.2.4 Unit Testing

Unit Testing allows the testing of small sections of source code. In this case, unit tests will help us to isolate the select packages that are within the scope of testing from the rest of the system.

Unit testing should focus on core code that is a dependency for other modules, code that regularly gathers bugs and code that is changed by a number of different developers. It should not cover trivial code, such as accessors and mutators, code with non-deterministic results or UI code.[8]
Mention Pareto principle again! Aim for 60-70% code coverage of business logic, ˜20% of the overall application.

1.2.5 Integration Testing

Java is a heavily object-oriented (OO) language. This will affect our testing as in this type of software, much of the complexity is moved from algorithms in methods, to the connection of software components[9, pp.236]. We will therefore need a much greater focus on integration testing than unit testing.

1.2.6 System Testing

While testing the system as a whole will not help us find low-level bugs, it should help to produce

System testing will also help us to verify the non-functional requirements that have been previously determined. In particular, our system testing will cover

While the system testing will be conducted using the MASON UI as a black-box test, thus requires functionality provided by classes outside the test scope, the test cases will only cover functionality provided by classes which are in scope.

Acceptance Testing is a particularly useful form of system testing. Acceptance Testing could be performed to determine if the software can be operated effectively by our end users. It can be useful for understanding the domain of our software better, but as we are not intending to further develop MASON, this is not particularly relevant here. It should be performed ON?/BY? domain experts?- I am NOT a domain expert..

While acceptance testing will not help us determine that the software is *dependable*, it would help to discover if it is appropriate for the target audience. In particular, our users have supposedly only received a basic level of Java training. It has been stated that MASON is less-suited to beginner programmers, when compared to other tools, such as NetLogo[10].

1.2.7 Regression Testing

Unfortunately neither the website nor the GitHub repository for MASON provide any previously implemented automated testing. Either this testing has not been done, which is common with freely-distributed software, or it has not been publicly distributed. As such, it will not be possible to run any regression testing as part of the project.

2 Test Case Specifications

2.1 Test Cases 1-3

As previously stated, our initial unit testing will focus on the simulation scheduler which provides the core functionality for MASON. This functionality is contained within the Schedule class as shown in Fig. 2. While this class initially appears to be quite large, at closer inspection, many of its methods are simply overloading others, due to Java's lack of real support for default function arguments.

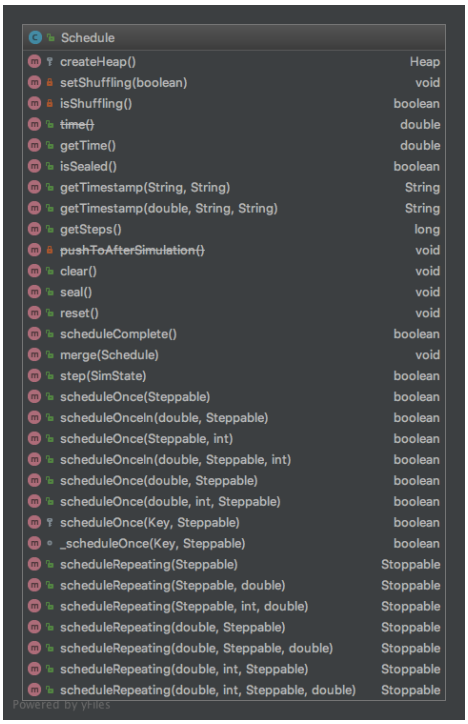


Figure 2: Schedule Class

By removing trivial methods (accessors, mutators, overloading methods), we can reduce the class down to:

- `getTimestamp`: Returns a given time in string format.
- `merge`: Merge a given schedule into this one.
- `step`: Moves the schedule forward by one implementation, skipping empty timesteps.
- `_scheduleOnce`: Adds the specified item to the schedule, to occur at the specified timestep.
- `scheduleRepeating`: Adds the specified item to the schedule, to repeat continously at specified interval.

By constructing a test that ensure the simulation `step` method works correctly, we will also indirectly test that the `_scheduleOnce` method works as expected during our setup process. `_scheduleOnce` is a private method, so this will be called indirectly by one of its overloading methods: `scheduleOnce(Steppable)`. Other overload methods could be used instead with little difference on the test as the scheduler skips any empty timesteps. This is **Test Case 1**. In order to facilitate this test, a simple `Increment` class (Fig. 4) has been created. The test will create a new scheduler and add a new instance of this class to it. The scheduler will be stepped a number of times (10) to ensure that the `Increment` value is correctly stepped.

Test Case 2 is similar, but will utilise the `scheduleRepeating(Steppable)` to ensure that the Schedule correctly manages recurring events. As mentioned, the scheduler skips

any empty timesteps, so providing a different start time or time interval will make little difference to the test.

Test Case 3 ...?

2.2 Test Case 4

2.3 Test Case 5

2.4 Test Case 6

2.5 Test Case 7

2.6 Test Case 8

3 Test Results

Case	Pass	Level	Expected	Actual	Details
1	✓	Unit	`i` variable is incremented once, in first simulation step.	`i` is incremented once, despite the simulation being stepped 10 times.	Behaved as expected, no notable side-effects.
2	✓	Unit	`i` variable is incremented once for each simulation step.	`i` is incremented ten times, once at each step.	Behaved as expected, no notable side-effects.
3	✓	Unit			
4	✓	Integration			
5	✓	Integration			
6	✓	Integration			
7	✓	System			
8	✓	System			

4 Test Summary Report

The significant limitations of testing resources reduce the level of confidence with which we can say that the software is free from defects. I can assure that the core functionality, including the simulation scheduler works.

5 References

[1] J. Spolsky, "Five Worlds," May 2002. [Online]. Available: https://www.joelonsoftware.com/2002/05/06/five-worlds/ [Accessed: Mar. 15, 2018]

[2] B. Leijedekkers. (2016, Sep) Metricsreloaded. [Online]. Available: https://plugins.jetbrains.com/plugin/93-metricsreloaded [Accessed: Apr. 10, 2018]

[3] R. S. Pressman, *Software Engineering: A Practitioner's Approach*, 8th ed. Boston ; London: McGraw-Hill Higher Education, 2010.

[4] T. Zimmermann, N. Nagappan, and A. Zeller, *Predicting Bugs from History.* Berlin, Heidelberg: Springer Berlin Heidelberg, 2008, p. 6988.

[5] C. Kaner, J. Bach, and B. Pettichord, *Lessons Learned in Software Testing: A Context-Driven Approach.* Wiley Computer Publishing, 2002.

[6] S. Luke, *Multiagent Simulation And the MASON Library*, 19th ed., George Mason University, Jun 2015. [Online]. Available: https://cs.gmu.edu/%7Eeclab/projects/mason/manual.pdf [Accessed: Mar. 28, 2018]

[7] K. Alden, J. Timmis, P. Andrews, H. Veiga-Fernandes, and M. Coles, "Pairing experimentation and computational modeling to understand the role of tissue inducer cells in the development of lymphoid organs," *Frontiers in Immunology*, vol. 3, p. 172, 2012. [Online]. Available: https://www.frontiersin.org/article/10.3389/fimmu.2012.00172

[8] K. Kapelonis, "Don't Test Blindly: The Right Methods for Unit Testing Your Java Apps," Jan 2013. [Online]. Available: https://zeroturnaround.com/rebellabs/dont-test-blindly-the-right-methods-for-unit-testing-your-java-apps/ [Accessed: Mar. 29, 2018]

[9] P. Ammann and J. Offuit, *Introduction to Software Testing.* Cambridge University Press, 2008.

[10] S. F. Railsback, S. L. Lytinen, and S. K. Jackson, "Agent-based simulation platforms: Review and development recommendations," *SIMULATION*, vol. 82, no. 9, pp. 609–623, 2006.

[11] *Basic MASON Model and its Relationship to GUI Controllers*, George Mason University. [Online]. Available: https://cs.gmu.edu/ eclab/projects/mason/docs/SimulatorLayout.pdf [Accessed: Apr. 10, 2018]

6 Appendix

Package	Lines of Code
sim.engine	2,961
sim.field	444
sim.field.grid	10,248
Total	13,653
Average	4,551

(a) Lines of Code

Package	Class Count
sim.engine	25
sim.field	6
sim.field.grid	14
Total	45
Average	15

(b) Class Count

Package	v(G)	
	Average	Total
sim.engine	2.43	374
sim.field	2.38	57
sim.field.grid	3.75	1,829
Total		2,260
Average	3.39	753.33

(c) Cyclomatic Complexity

Package	Dependencies	Dependants
sim.engine	2	54
sim.field	1	24
sim.field.grid	2	20
Average	1.67	32.67

(d) Package Dependency

Figure 3: Code Metrics for the relevant MASON libraries

```
class Increment implements Steppable{
        private int i = 0;

        @Override
        public void step(SimState state) {
                i++;
        }
}
```

Figure 4: Simple Increment class used for Unit Testing

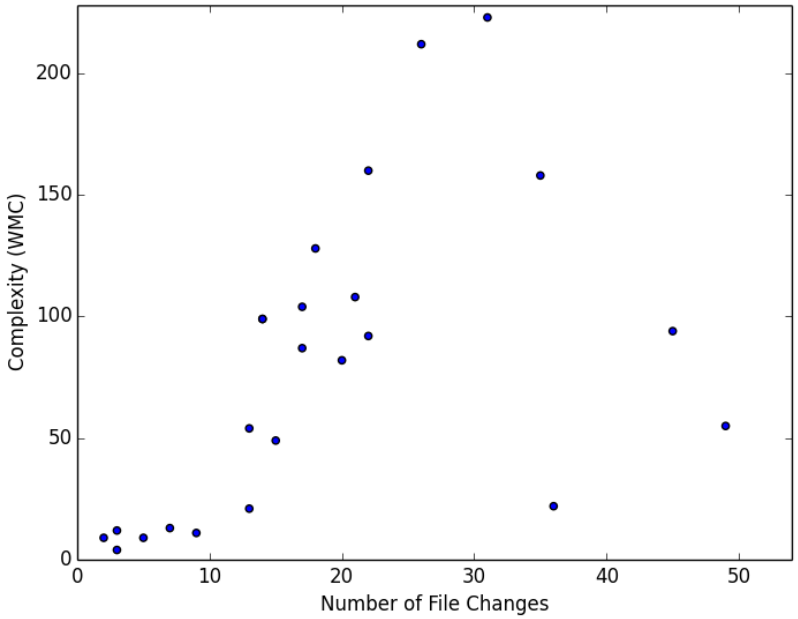


Figure 5: Cyclomatic Complexity and Number of File Revisions for classes in test scope

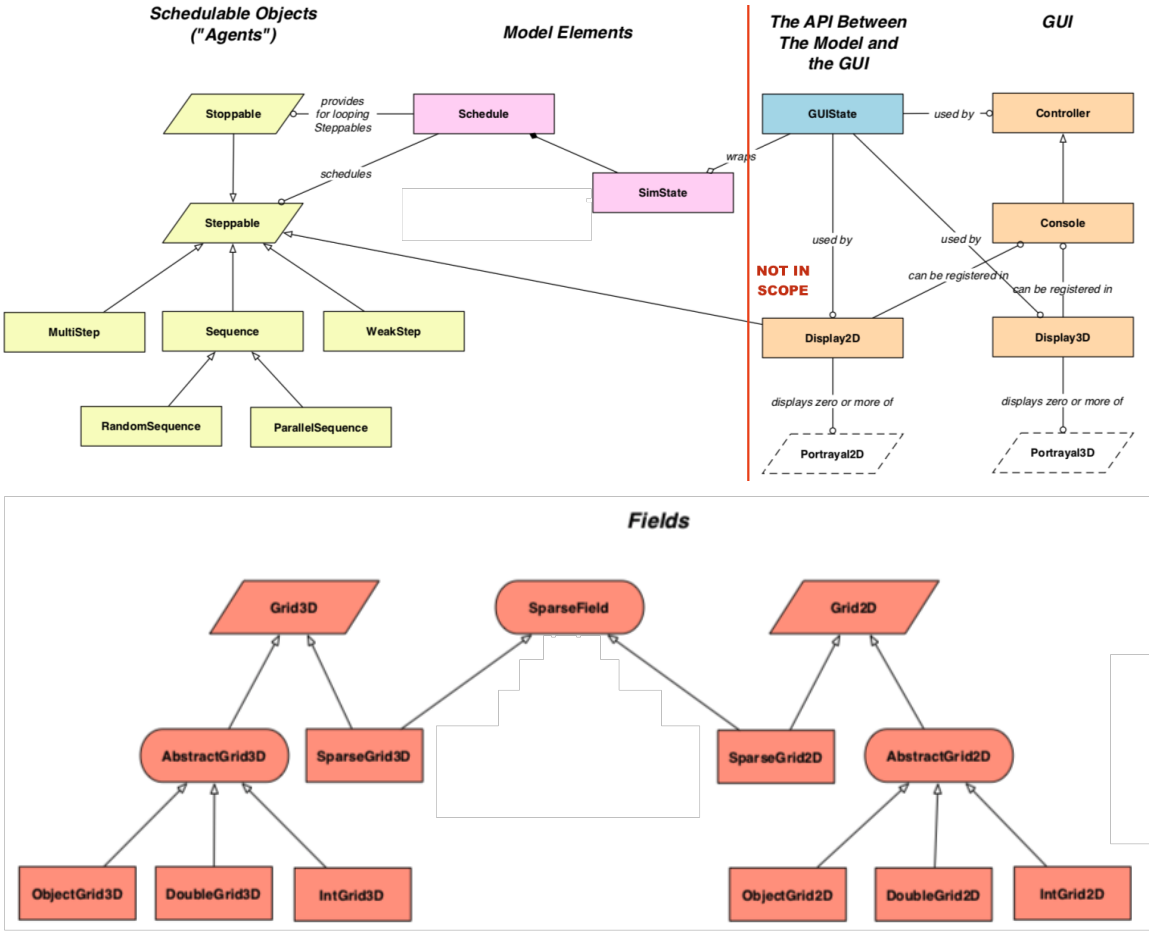


Figure 6: UML diagrams of hierarchy for classes in the test scope[11]

Package	Class	HeatBugs Coverage (%)		Virus Infection Coverage (%)		Mouse Traps Coverage (%)	
		Method	Line	Method	Line	Method	Line
sim.engine	AsynchronousSteppable						
	IterativeRepeat	60	70	60	70		
	MethodStep						
	MultiStep						
	ParallelSequence	38	59				
	RandomSequence						
	Repeat						
	Schedule	41	51	41	50	35	46
	Sequence	11	12				
	SimState	31	18	31	18	31	18
	TentativeStep						
	ThreadPool	66	76				
	WeakStep						
sim.field	SparseField	21	34	21	35		
sim.field.grid	AbstractGrid2D	10	1			5	0
	AbstractGrid3D						
	DenseGrid2D						
	DenseGrid3D						
	DoubleGrid2D	11	7				
	DoubleGrid3D						
	IntGrid2D					17	10
	IntGrid3D						
	ObjectGrid2D						
	ObjectGrid3D						
	SparseGrid2D	10	2				
	SparseGrid3D						

Figure 7: Code Coverage from Demo Simulation Runs