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Lab Package: Random Testing

Bachelor's Thesis (9 ECTS)

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Lab Package: Random Testing

Abstract:

The goal of this thesis is to create lab materials about automated unit test generation using Randoop for the course 'Software Testing' (LTAT.05.006) at the University of Tartu. This thesis gives an overview of the materials and tasks. The lab was executed during the spring semester of 2020. Feedback was gathered and analysed and future improvements are suggested.

Keywords:

Software testing, unit testing, lab package, Randoop, Java

CERCS:

P170 Computer science, numerical analysis, systems, control

Praktikumimaterjal: Stohhastiline testimine

Lühikokkuvõte:

Antud bakalaureusetöö eesmärk on luua praktikumimaterjalid ühiktestide automatiseeritud genereerimiseks kasutades Randoopi aine "Tarkvara Testimine" (LTAT.05.006) raames Tartu Ülikoolis. Töö annab ülevaate materjalidest ja ülesannetest. Praktikum viidi läbi 2020 kevadsemestril. Tagasiside koguti ja analüüsiti ning tehti soovitusel täiendusteks.

Võtmesõnad:

Tarkvara testimine, ühiktestimine, praktikumimaterjal, Randoop, Java

CERCS:

P170 Arvutiteadus, arvutusmeetodid, süsteemid, juhtimine

Table of Contents

Table of Contents	3
1 Introduction	4
2 Background Information	5
2.1 Course 'Software Testing'	5
2.2 Random Testing	6
2.2.1 Feedback-Directed Random Testing	6
2.3 Randoop	6
3 Lab design	8
3.1 Lab Schedule	8
3.2 Lab Materials	8
3.3 NextDate Application	9
3.4 Point-of-Sale System	9
3.5 Lab Session Tasks	9
3.6 Homework Tasks	10
3.7 Grading	11
4 Lab Execution	12
5 Feedback	13
5.1 Student Feedback	13
5.2 Feedback Analysis	14
5.3 Future Improvements	15
6 Summary and Conclusions	16
References	17
Appendix	18
Lab Materials	18
Student Lab Materials	18
Lab Supervisor Materials	18
Lab Source Code	18
Feedback Questionnaire	19
License	20

1 Introduction

Software testing is an integral part of the software development process. The goal of software testing is to create high quality software and to verify the product developed is ready for use. Students of Computer Science at the University of Tartu are introduced to software testing in the course ‘Software Testing’ (LTAT.05.006). The practical part of the course consists of eleven labs which introduce various tools and frameworks. The labs are designed for teaching a testing method and finding faults in the software.

Random testing is a software testing method where the tests are generated randomly and automatically. There are many tools available to automatically generate unit tests, such as Evosuite¹ and Randoop². Automatically generating unit tests will make the software development process more efficient. Automated test generation can also create test cases which the developer did not think of.

The aim of this thesis is to create a package of lab materials for the lab session titled ‘Random Testing’. The lab materials contain the instructions for students and lab supervisors, the systems to be tested, the grading scheme, in-lab and homework tasks.

The purpose of the lab is to teach students the basics of random testing and introduce them to the testing tool Randoop.

This thesis contains four main sections in addition to ‘Introduction’ and ‘Summary and Conclusions’. The first section gives relevant background information about the ‘Software Testing’ course, random testing, and the Randoop tool. The second section details the lab contents and materials. It also gives a grading scheme for the homework task. The third section gives an overview of what was done during the lab session. The fourth section details the feedback collection process and feedback analysis.

¹ <http://www.evosuite.org/>

² <https://randoop.github.io/randoop/>

2 Background Information

This section gives an overview of the course 'Software Testing' (LTAT.05.006) and the topics covered in the lab.

2.1 Course 'Software Testing'

'Software Testing' is a 6 ECTS course at the University of Tartu. The practical part of the course consists of 11 lab sessions [4].

- 1) Debugging
- 2) Black-Box Testing
- 3) Combinatorial Testing
- 4) White-Box Testing
- 5) Random Testing
- 6) Automated Web Application Testing
- 7) Web-Application Testing in the CI/CD Pipeline
- 8) Automated GUI Testing
- 9) Mutation Testing
- 10) Static Code Analysis
- 11) Document Inspection and Defect Prediction

The course is taken by Computer Science students in the fourth semester. The course outline states that it will give an overview of various software defects, as well as the organisational aspects of software testing [4].

2.2 Random Testing

Random testing is an approach to software testing which requires minimal manual intervention. Rather, the inputs to a program are generated randomly based on predefined boundaries. One of the main difficulties about random testing is the lack of a test oracle [6].

Random testing can be used for all levels of testing. Most random testing tools take program code as input and generate a unit test suite.

2.2.1 Feedback-Directed Random Testing

Feedback-directed random testing is a technique which 'builds inputs incrementally by randomly selecting a method call to apply and finding arguments from among previously-constructed inputs [5].' The inputs are checked against method signatures and filters which determine the validity of the input. Valid input sequences can be reused and extended to generate longer and more comprehensive test cases [5].

2.3 Randoop

'Randoop is a unit test generator for Java. It automatically creates unit tests for your classes, in JUnit format [3].' Randoop is a tool which implements the feedback-directed random testing algorithm. Additionally, Randoop makes some practical improvements to test generation.

To guarantee identical conditions, Randoop prevents method calls which change the state of the underlying system, such as database update operations. Randoop also filters lexically redundant tests to improve performance [7].

Randoop generates two types of tests - error-revealing and regression tests. Error-revealing tests are tests which failed and potentially revealed a bug. Error-revealing tests are generated when an unexpected exception is thrown or one of

the predefined contracts is violated. Regression tests are tests which passed and can be added to the test suite [3].

The input and output of Randoop can be modified by the use of flags. Custom primitive input values can be specified by the use of *--literals-file*. Currently Randoop does not support specifying more complex objects or data structures. There are flags available to specify the classification of various exceptions [3].

Although the tool can generate test cases which the developer did not think of, there can also be cases the developer would not think of. An example of such a case is an input which would take thousands of years to calculate. Therefore Randoop should not be trusted blindly and the generated test cases should be reviewed.

3 Lab design

This section gives an overview of the lab schedule, materials for students and lab supervisors, and tasks for the students complete with the grading schema.

3.1 Lab Schedule

The lab session consists of two main parts:

- The introduction to random testing and Randoop setup should take approximately 70 minutes. Students are expected to get Randoop to work and show Randoop usage to the lab supervisor.
- The explanation of homework tasks should take approximately 20 minutes.

3.2 Lab Materials

The author of this thesis created the following materials for the lab 'Random Testing':

- Lab instructions for students which contain:
 - An introduction and manual for Randoop,
 - In-lab, and homework tasks.
- The source files for the Point-Of-Sale program, which are required for the homework tasks.
- Lab instructions for supervisors which contain:
 - Additional info and guidelines compared to the student version,
 - Presentation slides,
 - Model solution,
 - Detailed grading schema.

Additionally, the in-lab and homework tasks use the NextDate application, which is a part of the pre-existing course materials made for the lab 'White-Box Testing'.

The links to the lab materials can be found in Appendix I.

3.3 NextDate Application

The NextDate application is part of the ‘Software Testing’ course materials for the lab ‘White-Box Testing’. The author of this thesis chose to use this application because it clearly demonstrates a key weakness of random testing - the lack of test oracles. When a test suite for NextDate is generated by Randoop, it will generate no error-revealing tests.

Additionally, the code coverage reached by Randoop with the default configuration is very low. By modifying the configuration, reasonable code coverage can be reached.

3.4 Point-of-Sale System

The Point-of-Sale (POS) System is a simplified version of the application used in the course ‘Software Engineering’ (LTAT.05.003). The author of this thesis chose to use this application because it clearly exemplifies the software development cycle using Randoop. The POS system supports adding items to a shopping cart and making a transaction. There are two seeded faults in the system which the students have to analyze.

3.5 Lab Session Tasks

The purposes of the lab session tasks are the following:

1. Give an introduction to students about random testing and Randoop
2. Help students set up Randoop
3. Give an explanation of the homework tasks

The lab should start with the lab supervisor giving a brief overview of random testing. The lab supervisor will then introduce Randoop. It is important to introduce the workflow, which is explained in more detail in the lab instructions ‘Randoop’ section (see

Appendix I). He will then show an example of a Randoop command and explain the different parts of the command in detail.

The students will then download and install the necessary tools. It is expected that there are some issues with setting up Java 8 properly, since there are a lot of details involved. The main goal is getting a Randoop command to run and generate tests for the first time. The lab supervisor will help the students when they run into issues. Most troubleshooting is also covered in the lab instructions.

After getting Randoop working, the students must show their progress to the lab supervisor. When all the students have Randoop working, the lab supervisor will introduce the homework tasks, which concludes the lab.

3.6 Homework Tasks

The homework consists of using Randoop to test the NextDate and POS applications introduced in sections 3.3 and 3.4 respectively and analysing the test results.

The first homework task is to use Randoop to test the NextDate application. A test suite will be generated and it will have no error-revealing tests. The test suite also will also have very low code coverage. The purpose of this task is to demonstrate the main weakness of random testing - not having a test oracle. The students will also have to improve upon the default configuration of Randoop to improve code coverage. This will familiarize students with Randoop and its possibilities.

The second homework task is testing the POS system. The purpose of this task is to familiarize students with the software development workflow using Randoop. They will analyze the error-revealing tests, which are generated because of the seeded faults. Fault analysis and investigation is a necessary skill for a software tester in a more general sense.

3.7 Grading

It is possible to earn a maximum of 10 points for this lab. The grading schema is as follows:

- 1 point for lab attendance
- 5 points for testing and analyzing the NextDate application
- 4 points for testing and analyzing the POS system

A more detailed explanation of the grading schema is available in the lab instructions (see Appendix I).

4 Lab Execution

The Random Testing labs were given to 4 groups of students on 17th and 18th March 2020. The author of this thesis was present in 2 lab sessions on March 17. Due to the lockdown regarding COVID-19, the labs were carried out online.

In the first lab session there were 5 students present. The lab supervisor presented the topic in approximately 15 minutes. She instructed students to follow the materials for the setup and assisted them with issues. All the students had Randoop working by approximately 60 minutes. The lab supervisor explained the homework and answered additional questions, which took 15 minutes. With a higher participation, it is probable that assistance and answering questions would have taken longer and the lab execution timing would have matched the schedule in section 3.1.

In the second lab session there were 16 students present. The lab supervisor presented the topic in more detail in roughly 25 minutes. He then went through the student instruction and gave enough time for students to follow along to perform the in-lab tasks. This resulted in relatively fewer students needing assistance with the setup. At approximately 70 minutes, all the students had Randoop set up. The lab supervisor gave an explanation of the homework, gave suggestions and answered questions. The lab execution went exactly as planned.

The issues that students encountered were planned for and were often the result of missing a detail in the instructions. The most common issue was setting up Java 8, since Randoop requires Java 8, which is not the latest stable version. Therefore, most students had to install and set up their system to use Java 8. The lab supervisors had experience with the problems and could also refer to the solution in the instructions.

5 Feedback

This section includes an overview of the student feedback and its analysis. There are also suggestions made by the author of this thesis for future improvements based on the lab execution and feedback.

5.1 Student Feedback

One week after the lab execution, the students were asked to fill out the online feedback form. The form consisted of 7 statements and a field to give additional feedback. The statements were following:

1. The goals of the lab were clearly defined and communicated
2. The tasks of the lab were clearly defined and communicated
3. The instructions of the lab were appropriate and helpful
4. The tools used in the lab were appropriate and useful
5. Compared to the previous labs, the homework assignment was more difficult
6. Overall, what I learned in the lab is relevant for working in the software industry
7. Overall, the lab was interesting and inspiring

The students had to evaluate the statements on a scale of 1 (strongly disagree) to 5 (strongly agree). In total, 120 students did the homework and 36 replied to the feedback form. The summary of the feedback is visible in Figure 1.

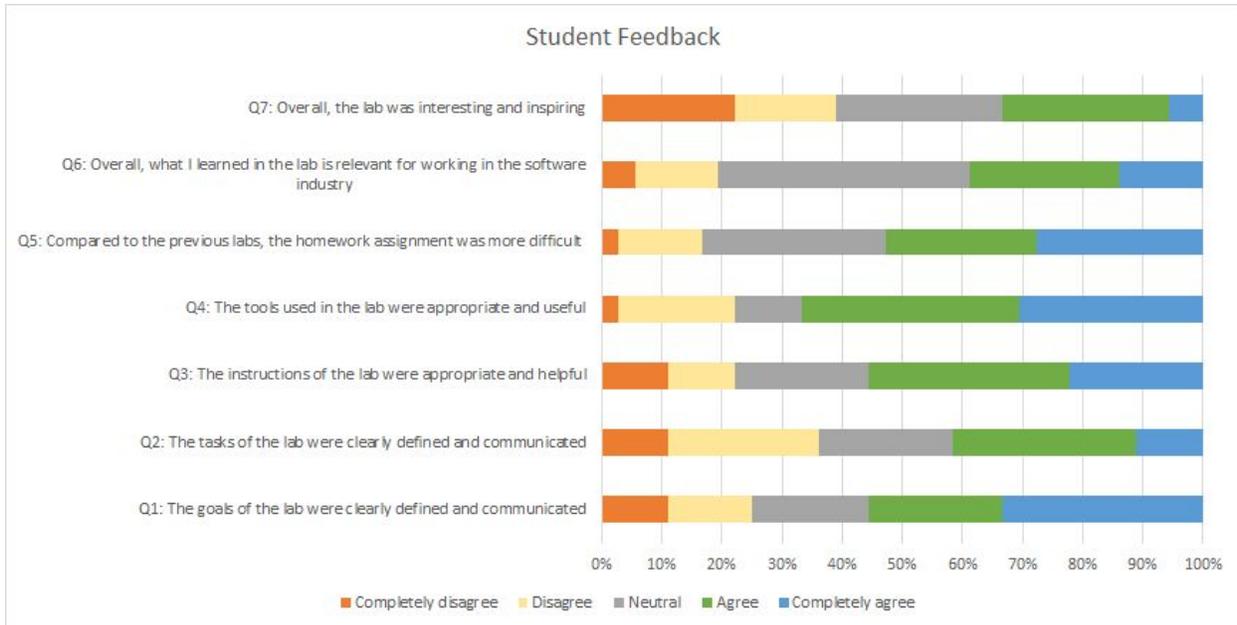


Figure 1. Summary of student feedback

5.2 Feedback Analysis

The first question asked whether the goals of the lab were clearly defined and communicated. 56% of respondents agreed with the statement, 19% were neutral and 25% did not agree. Clearly understanding the goals and reasons is an important part of studying, therefore the goals could be emphasized more in the materials.

42% of respondents found the tasks clearly defined and communicated, 22% of respondents were neutral and 36% of respondents did not understand the tasks clearly. Since a high relatively high percentage of respondents disagreed with this statement, clarifying the materials should be considered.

The third question asked whether the respondents found the lab instructions appropriate and helpful. 56% agreed with the statement, 22% were neutral and 22% did not agree. This indicates that the instructions could be made clearer and more comprehensive.

The respondents strongly found the tools used in the lab appropriate and useful, as 67% of the respondents agreed with the statement. 33% of the respondents disagreed

or were neutral. This is a satisfactory result, since Randoop depends on Java 8, which is becoming outdated.

53% of the respondents found the homework more difficult than the other homeworks, 32% were neutral and 19% disagreed. This is an expected result, since the two preceding labs were relatively easier. It is also likely that since the respondents did not find the tasks clearly communicated, the homework seemed more difficult.

Question six asked whether the respondents thought what they learned would be relevant in the software industry. 39% thought that the knowledge would be useful. 42% of respondents were neutral, which is understandable since it is difficult to predict the future working environment and practices. 19% of the respondents disagreed with the statement.

Question seven asked whether the respondents found the lab inspiring. 33% found the lab inspiring, 28% were neutral and 39% of the respondents disagreed. The fact that so many respondents disagreed or were neutral shows that the lab should be made more interesting.

Overall, the feedback was positive and the execution was successful. The additional feedback also emphasized issues regarding the setup and the clarity of tasks.

5.3 Improvements

Based on the student feedback and discussion with the course staff, the following improvements were made to the lab instructions:

1. Clarification of lab submission deliverables
2. Simplification of the grading schema
3. Additional instructions in the section 'Troubleshooting'

6 Summary and Conclusions

The goal of this thesis was to create lab materials for the course 'Software Testing' (LTAT.05.006) in the University of Tartu. The lab package contained materials for the students as well as additional instructions for the lab supervisors. The lab was carried out in the 2020 spring semester.

The lab execution went smoothly and feedback was collected from 36 students one week after the lab execution. The feedback was mostly positive. After the analysis of feedback, improvements were made to the lab materials. Based on the feedback, the lab materials met course requirements and can be used in the course 'Software Testing' in the future.

References

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Appendix

I. Lab Materials

Student Lab Materials

- Lab instructions “Random Testing” PDF file

<https://courses.cs.ut.ee/2020/SWT2020/spring/uploads/Main/SWT2020L5-Instr-v1.pdf>

- Lab instructions “Random Testing” PDF file (improved after student feedback)

<https://drive.google.com/file/d/1fSOwIOILtGMjWBRV3JVVF2ju2aQ9U5e6/view>

Lab Supervisor Materials

- Lab instructions “Random Testing” PDF file
- Model solution for the lab “Random Testing”, which consists of the following:
 - Model solution report PDF file,
 - Model solution screenshots,
 - Model solution test suites,
 - Model solution configuration files.

For confidentiality reasons, the lab supervisor version is not public, but can be made available on request.

Lab Source Code

- NextDate Java Project

<https://courses.cs.ut.ee/2020/SWT2020/spring/uploads/Main/nextdate.zip>

- Point-Of-Sale Java Project

https://courses.cs.ut.ee/2020/SWT2020/spring/uploads/Main/pos_180320.zip

II. Feedback Questionnaire

Feedback to Lab 5 - Random Testing with Randoop

Form description

Name (optional)

Short answer text

Q1: The goals of the lab were clearly defined and communicated *

1 2 3 4 5

Completely disagree Completely agree

Q2: The tasks of the lab were clearly defined and communicated *

1 2 3 4 5

Completely disagree Completely agree

Q3: The instructions of the lab were appropriate and helpful *

1 2 3 4 5

Completely disagree Completely agree

Q4: The tools used in the lab were appropriate and useful *

1 2 3 4 5

Completely disagree Completely agree

Q5: Compared to the previous labs, the homework assignment was more difficult *

1 2 3 4 5

Completely disagree Completely agree

Q6: Overall, what I learned in the lab is relevant for working in the software industry *

1 2 3 4 5

Completely disagree Completely agree

Q7: Overall, the lab was interesting and inspiring *

1 2 3 4 5

Completely disagree Completely agree

Here you can add additional feedback

Long answer text

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