JUnitMe2.0 : JUnit tests generation with Alloy and CodeModel

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16th December 2015

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Introduction

"Every program is guilty until proven innocent".

During the development phase, developers spend lots of time writing tests for code they have written. But these tests can be very so tedious and repetitive, that developers sometimes botch or simply skip this very important part of software development.

But what if developers didn't have to spend hours writing tests to find bugs and have a good code coverage of their program? What if there was a magic stick that can generate a bunch of unit tests?

Since Java is one of the most used programming languages nowadays, we implemented a solution that would generate automatically Java unit tests. That would save time for developers, and give the time and the energy to focus on working on the business layer.

This project is an extended version of an application developed by Valentin Lefils and Quentin Marrecau [1] [2] . The first version of the application treated the same problems we are facing, but only on small examples of Java programs.

In this project, we present our tool: JUnitMe2.0. Our tool can generate automatically Java unit tests for any Java open source application. From a description of specification, our tool generate all instances that covere the data specifications, then generate the unit tests corresponding to these instances.

Chapter 1

Technical work

1.1 Goal

The goal of this tool is to generate a large amount of Java unit tests automatically so that we can achieve a good coverage of code with no time or effort spent. Therefore developers can focus on developing the business layer without worrying about testing the code they have written. Our tool can be used to verify that no bugs will occur when objects of the program interact with each other. In other words, our tool can verify that there no actual error exists for an application.

1.2 Overview

The main idea behind our project is to define the structure of a given Java program and to export collection of constraints that describes this structure. After analyzing these constraints, if possible, we generate all instances that satisfy the constraints.
By translating these instances to Java and then generating Java unit tests, we can obtain a good code coverage automatically.

1.3 Architecture & Design

UML

1.4 Algorithm

1.4.1 Java to Alloy

Generating Alloy source code

Base model The base model is a meta-model, It is the base of the generated java to Alloy program. It is composed of four parts: Types, methods, methods constraints and methods arguments.

Types All types have a super-type: *Type*. In addition, every object has a type and a constructor.

```
abstract sig Type{
}

sig Object{
    type : Type,
    constructor : ConstructorCall
}
```

Methods A very important thing in order to simulate an execution trace, is to have the trace of execution with successive methods calls and not only instances of objects of simple type declaration. Successive methods calls can be presented in a linked list, so later on, simply by getting the head of the list we can browse a gernerated instance and we will have an access to method calls. The following Alloy code represents how we have represented methods in Alloy model.

```
sig ConstructorCall{
    paramTypes: seq Type
}

abstract sig Call{
}

one sig End extends Call{
}

abstract sig CallWithNext extends Call{
    nextMethod : Call
}
```

```
sig MethodCall extends CallWithNext{
    receiver : Object,
    method : Method,
    params : seq Object
}

one sig Begin extends CallWithNext{
}

abstract sig Method {
    paramTypes : seq Type,
    receiverType : Type
}
```

Constraints Methods in every instance generated later on should respect numerous constraints, such like a method not being able to call itself. The following Alloy code represents the constraints used in the Alloy model.

```
------ Method Constraints-------

-- There should be one and only method.next= end
fact{
    one m : MethodCall • m.nextMethod in End
}

-- Method call can't be linked to itself
fact{
    all mc : MethodCall • mc.nextMethod≠mc
}

-- Reciever has the right type
fact{
    all mc : MethodCall •  mc.receiver.type=mc.method.receiverType
}

-- Call can't be done twice
fact{
all mc: MethodCall • no mc2 : MethodCall •  (mc2 in mc.^nextMethod) ∧ (mc2.nextMethod=mc)
}

-- All methods calls has been called
fact{
    all mc : MethodCall • one c : CallWithNext • c.nextMethod=mc
}

-- Object which calls a method has the right type
fact{
    all mc:MethodCall • mc.receiver.type=mc.method.receiverType
}
```

Arguments Primitve types has been included in the base model. All other used types in a given program are generated at runtime.

```
------- Param Constraints ------

-- Types verification
fact{
    all mc : MethodCall •validParam[mc.method,mc]
}

pred validParam[method : Method, call : MethodCall]{
        call.params.type=method.paramTypes
        #call.params=#method.paramTypes
    all  pt : method.paramTypes.elems • all p : call.params.elems • call.params.idxOf[p]=
        method.paramTypes.idxOf[pt] implies pt=p.type
}

-------- Primitive Types ------------

one sig Gen_Double extends Type{}
one sig Gen_Integer extends Type{}
one sig Gen_Float extends Type{}
one sig Gen_Boolean extends Type{}
one sig Gen_Byte extends Type{}
one sig Gen_Character extends Type{}
one sig Gen_Long extends Type{}
one sig Gen_Short extends Type{}
```

Generating Alloy Code To generate Alloy instances for an existing Java program we used Spoon(1.5). Spoon uses AST (Abstract syntax tree)[3] to browse the structure of a specified program. With informations collected in the AST, we are able to generate the code of Alloy program corresponding to the initial Java program. The generated code is then grafted to the base model. Result is a complet Alloy model inside the file FinalGen.als

Data: Java source code
Result: Alloy model
foreach *class c* **do**
  Modify the name of class from *package.class* to *package_class*;
  Add *ClassName* as a type to Alloy file;
  foreach *method m in c* **do**
    Create method name as: $className\_MethodName\_NumberOflineInJavaFile$;
    Add a *Sig* extending $Method\{\}$ representing the method m into Alloy model;
    Add to Alloy model number of method parameters as a $fact$;
    foreach *Parameter p in m* **do**
      Add to Alloy model the type of p as a $fact$;
    end
    Add to Alloy model the type of *receiver* as a $fact$;
  end
  foreach *Constructor ct in c* **do**
    Add a *Sig* extending $ConstructorCall\{\}$ representing the constructor ct in to Alloy model;
    Add to Alloy model number of constructor parameters as a $fact$;
    foreach *Parameter p in ct* **do**
      Add to Alloy model the type of p as a $fact$;
    end
  end
end

Algorithm 1: How to transfer Java code to Alloy model

An example of the results output:

```
sig package_myClass extends Type{}
sig package_myClass_method_1 extends Method{}
fact{
  #package_myClass_method_1.params=3
  package_myClass_method_1.param[0].type=typeArg1
  package_myClass_method_1.param[1].type=typeArg2
  package_myClass_method_1.param[2].type=typeArg3
  package_myClass_method_1.receiverType=X
}
```

1.4.2 Alloy to Java

Generating Java unit tests

Modelizing Alloy instances in Java Using Alloy Analyzer we execute the generated Alloy source code. Alloy Analyzer generates all possible instances. Each instance is a solution, we can obtain a solution using A4Solution object. A4Solution object has a method *satisfiable* to check if the solution is valid and a method *next* to go the next possible solution.

Creating Java object Each alloy instance is represented by a Java object called: *AlloyInstance*.

Generating tests In order To generate the code of Java unit tests we used CodeModel, which allows us to generate Java classes in a simple way.
We browse Java modelized solution and generate the variables used to call methods and the variables passed as methods parameters.
For each solution we use the execution trace. Firstly, we initalize all the necessary types for the receiver method, then all the veriables that will be used in parameters.

Data: Alloy instance modelized in Java
Result: Java unit test
foreach *Alloy Instance modelized in Java* **do**
  Get the head of method calls list;
  while *methods calls are not finished* **do**
    Create method signature;
    Add *org.Junit.Test* annotation ;
    Add *ThrowException* to method signature;
    Create a *trycatch* block;
    Inside a *try* block:{
    - Declare all variables
    - Call constructors
    - Add method calls with the necessary parameters
    };
  end
end

Algorithm 2: How to transfer an Alloy instance modelized in Java to Java unit test

An example of the results output:

```
@BeforeClass
public static void initExceptionBuilder() throws IOException {
        ExceptionLogger.initLogFile();
}

@Test
public void test0() throws Exception {
  try {

  }catch(java.lang.Exception x){
        ExceptionLogger.logException(x);
        throw(x);
  }
}

@AfterClass
public static void closeExceptionBuilder() throws IOException {
   ExceptionLogger.closeLogFile();
}
```

1.5 Implementation

In order to realise our project we have used four different techonologies: Spoon, Alloy, Alloy Analyzer and CodeModel.
The main parts of our project is generating Alloy source code from a given Java program, then generating Alloy instances. Thereafter modelizing these instances in Java to, finally, convert these modelized instances to Java unit tests.

Spoon

In order to analyze and transform source code, we needed an efficient and powerful library. We have chosen Spoon, a high-quality open-source library created and maintained by INRIA (French Institute for Research in Computer Science and Automation (French: Institut national de recherche en informatique et en automatique)). Providing a complete and fine-grained JAVA metamodel, Spoon enables us to perform effortless treatments in differents parts of code. These treatments are performed by processors, which are able to browse, modify, or even add any program element (class, method, field, statements, expressions...).[4][5] Spoon can also be used on validation purpose, to ensure that your programs respect some programming conventions or guidelines, or for program transformation, by using a pure-JAVA template engine.[6]

Alloy

Alloy is a language for describing structures and a tool for exploring them. It has been used in a wide range of applications from finding holes in security mechanisms to designing telephone switching networks. An Alloy model is a collection of constraints that describes (implicitly) a set of structures, for example: all the possible security configurations of a web application, or all the possible topologies of a switching network.[7]

Alloy Analyzer

Alloy Analyzer, is a solver that takes the constraints of a model and finds structures that satisfy them. It can be used both to explore the model by generating sample structures, and to check properties of the model by generating counterexamples.[7]

CodeModel

CodeModel is a Java library for code generators; it provides a way to generate Java programs in a way much nicer than PrintStream.println(). With CodeModel, we can build the java source code by first building AST (Abstract syntax tree)[3], then writing it out as text files that is Java source files.[8]

1.6 Utilisation

Chapter 2

Evaluation

2.1 Complexity

2.2 Performance

2.3 Ease of use

2.4 Limitations

Generic types
Lists
Tables

Conclusion

Using Spoon Java library to analyze and trasform source code, Alloy a language and tool for relational models, Alloy Analyzer a solver that takes the constraints of a model and finds structures that satisfy them and CodeModel a Java library for code generators we have succeeded in creating a tool capable of generating Java unit tests a given Java program. Our tool can verify that there no actual error exists for an application. This tool can be extended in future to be able to treat a bigger variety of java program. Today, our tool has been tested on ***** and it is able to generate Java unite tests that can achieve up to **% of code coverage.

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