Aiding the integration of automatically generated tests into pre-existing manually written test suites

Bryn Loftness

Colorado Mesa University

Research Advisor:

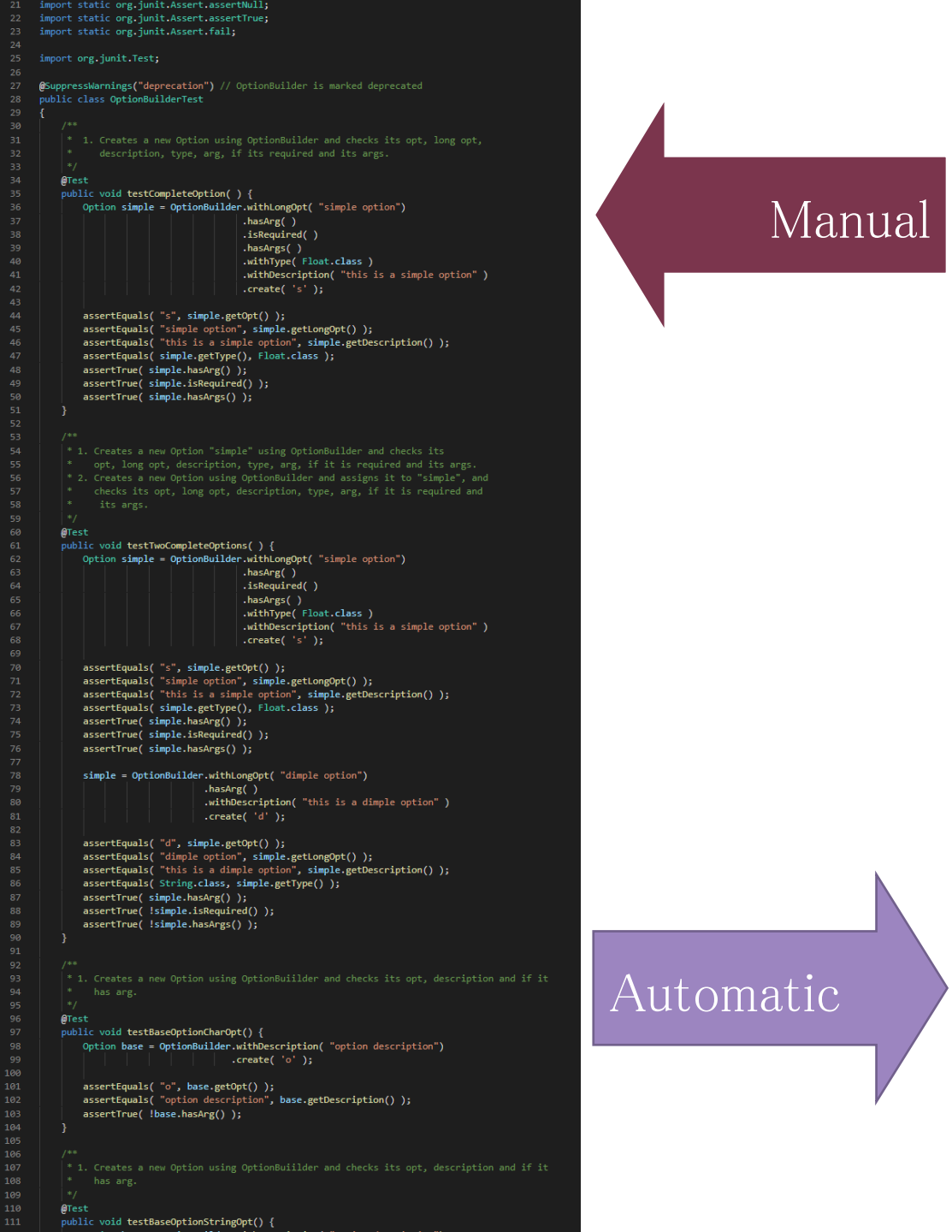
Dr. Venera Arnaoudova

Graduate Student Advisor:
Devjeet Roy

The Problem

Test Suite Reduction through the merging of redundant tests

Identifying optimal approach for selection of automatically generated tests for integration with similar manually written tests



```
import static org.junit.Assert.assertNull;
import static org.junit.Assert.assertTrue;
import static org.junit.Assert.fail;

import org.junit.Test;

@SuppressWarnings("deprecation") // OptionBuilder is marked deprecated
public class OptionBuilderTest
{
    /**
     *  1. Creates a new Option using OptionBuilder and checks its opt, long opt,
     *     description, type, arg, if its required and its args.
     */
    @Test
    public void testCompleteOption( ) {
        Option simple = OptionBuilder.withLongOpt( "simple option")
                                     .hasArg( )
                                     .isRequired( )
                                     .hasArgs( )
                                     .withType( Float.class )
                                     .withDescription( "this is a simple option" )
                                     .create( 's' );

        assertEquals( "s", simple.getOpt() );
        assertEquals( "simple option", simple.getLongOpt() );
        assertEquals( "this is a simple option", simple.getDescription() );
        assertEquals( simple.getType(), Float.class );
        assertTrue( simple.hasArg() );
        assertTrue( simple.isRequired() );
        assertTrue( simple.hasArgs() );
    }

    /**
     * 1. Creates a new Option "simple" using OptionBuilder and checks its
     *    opt, long opt, description, type, arg, if it is required and its args.
     * 2. Creates a new Option using OptionBuilder and assigns it to "simple", and
     *    checks its opt, long opt, description, type, arg, if it is required and
     *     its args.
     */
    @Test
    public void testTwoCompleteOptions( ) {
        Option simple = OptionBuilder.withLongOpt( "simple option")
                                     .hasArg( )
                                     .isRequired( )
                                     .hasArgs( )
                                     .withType( Float.class )
                                     .withDescription( "this is a simple option" )
                                     .create( 's' );

        assertEquals( "s", simple.getOpt() );
        assertEquals( "simple option", simple.getLongOpt() );
        assertEquals( "this is a simple option", simple.getDescription() );
        assertEquals( simple.getType(), Float.class );
        assertTrue( simple.hasArg() );
        assertTrue( simple.isRequired() );
        assertTrue( simple.hasArgs() );

        simple = OptionBuilder.withLongOpt( "dimple option")
                              .hasArg( )
                              .withDescription( "this is a dimple option" )
                              .create( 'd' );

        assertEquals( "d", simple.getOpt() );
        assertEquals( "dimple option", simple.getLongOpt() );
        assertEquals( "this is a dimple option", simple.getDescription() );
        assertEquals( String.class, simple.getType() );
        assertTrue( simple.hasArg() );
        assertTrue( !simple.isRequired() );
        assertTrue( !simple.hasArgs() );
    }

    /**
     * 1. Creates a new Option using OptionBuiilder and checks its opt, description and if it
     *    has arg.
     */
    @Test
    public void testBaseOptionCharOpt() {
        Option base = OptionBuilder.withDescription( "option description")
                                   .create( 'o' );

        assertEquals( "o", base.getOpt() );
        assertEquals( "option description", base.getDescription() );
        assertTrue( !base.hasArg() );
    }

    /**
     * 1. Creates a new Option using OptionBuiilder and checks its opt, description and if it
     *    has arg.
     */
    @Test
    public void testBaseOptionStringOpt() {
```

Manual

Automatic

```
/*
 * This file was automatically generated by EvoSuite
 * Mon Sep 11 18:52:57 GMT 2017
 */

package org.apache.commons.cli;

import org.junit.Test;
import static org.junit.Assert.*;
import static org.evosuite.runtime.EvoAssertions.*;
import org.apache.commons.cli.Option;
import org.apache.commons.cli.OptionBuilder;
import org.evosuite.runtime.EvoRunner;
import org.evosuite.runtime.EvoRunnerParameters;
import org.junit.runner.RunWith;

@RunWith(EvoRunner.class) @EvoRunnerParameters(mockJVMNonDeterminism = true, useVFS = true, useVNET =
public class OptionBuilder_ESTest extends OptionBuilder_ESTest_scaffolding {

  /**
   * 1. Creates a new OptionBuilder using method withType of OptionBuilder
   *    and checks if it is not null.
   */
  @Test(timeout = 4000)
  public void test00()  throws Throwable  {
      Class<Object> class0 = Object.class;
      OptionBuilder optionBuilder0 = OptionBuilder.withType((Object) class0);
      assertNotNull(optionBuilder0);
  }

  /**
   * 1. Calls method "isRequired" of OptionBuilder.
   * 2. Creates a new OptionBuilder and checks if it is
   *    required and if its args are equal to -1.
   */
  @Test(timeout = 4000)
  public void test01()  throws Throwable  {
      OptionBuilder.isRequired();
      Option option0 = OptionBuilder.create("SQT$h");
      assertTrue(option0.isRequired());
      assertEquals((-1), option0.getArgs());
  }

  /**
   * 1. Calls method withLongOpt of OptionBuilder with argument "org.apache.commons.cli.OptionBuilder"
   * 2. Creates a new OptionBuilder using method create of OptionBuilder and checks if its args equals
   */
  @Test(timeout = 4000)
  public void test02()  throws Throwable  {
      OptionBuilder.withLongOpt("org.apache.commons.cli.OptionBuilder");
      Option option0 = OptionBuilder.create("");
      assertEquals((-1), option0.getArgs());
  }

  /**
   * 1. Calls method withArgName of OptionBuilder with argument "SQT$h"
   * 2. Creates a new OptionBuilder using method create of OptionBuilder and checks if its args equals
   */
  @Test(timeout = 4000)
  public void test03()  throws Throwable  {
      OptionBuilder.withArgName("SQT$h");
      Option option0 = OptionBuilder.create("SQT$h");
      assertEquals((-1), option0.getArgs());
  }

  /**
   * 1. Calls method hasOptionalArgs of OptionBuilder with argument 0
   * 2. Creates a new OptionBuilder using method create of OptionBuilder and checks if it has optiona
   *    and if its args equals 0.
   */
  @Test(timeout = 4000)
  public void test04()  throws Throwable  {
      OptionBuilder.hasOptionalArgs(0);
      Option option0 = OptionBuilder.create("");
      assertTrue(option0.hasOptionalArg());
      assertEquals(0, option0.getArgs());
  }

  /**
   * 1. Calls method hasArgs of OptionBuilder with argument 61
```

Our Approach

- Manual process is arduous and complex, even with test case scenarios and identifier renaming
- The systematic nature of our approach simulates a manual experts process of by-hand clustering:
  - Analyze jUnit manually written tests with Evosuite automatically written tests (in Java)
  - Identify key features of similarity
  - isolate and relate test cases based on the key features
  - Apply NLP-based information retrieval on key features to identify model(s) that best reduce false positive rates from the cluster list

Evaluation and Current Results

- We create an oracle based on results from manual clustering, we then evaluate model performance based on this oracle
- Clustering identifies groups of two or more test cases that are similar, our oracle simplifies these clusters into one-to-one matches
- Current approach narrows down potential one to one matches by over 50%

Identifying information that could help us categorize and find similar test cases…

```
/**
 *  1. Creates a new Option using OptionBuilder and checks its opt, long opt,
 *     description, type, arg, if its required and its args.
 */
@Test
public void testCompleteOption( ) {
    Option simple = OptionBuilder.withLongOpt( "simple option")
                                 .hasArg( )
                                 .isRequired( )
                                 .hasArgs( )
                                 .withType( Float.class )
                                 .withDescription( "this is a simple option" )
                                 .create( 's' );

    assertEquals( "s", simple.getOpt() );
    assertEquals( "simple option", simple.getLongOpt() );
    assertEquals( "this is a simple option", simple.getDescription() );
    assertEquals( simple.getType(), Float.class );
    assertTrue( simple.hasArg() );
    assertTrue( simple.isRequired() );
    assertTrue( simple.hasArgs() );
}
```

[1, creates, a, new, option, using, option, builder, and, checks, its, opt, long, opt, description, type, arg, if, its, required, and, its, args]

[public, void, test, complete, option, option, simple, option, builderwith, long, opt, simple, option, has, arg, is, required, has, args, with, type, floatclass, with, description, this, is, a, simple, option, create, s, assert, equals, s, simpleget, opt, assert, equals, simple, option, simpleget, long, opt, assert, equals, this, is, a, simple, option, simpleget, description, assert, equals, simpleget, type, floatclass, assert, true, simplehas, arg, assert, true, simpleis, required, assert, true, simplehas, args]

…Sequencing of words/keywords, similar words and keywords. And…

<?xml version="1.0" encoding="
<root>
<function>
<annotation>
@
<name>
Test
</name>
</annotation>
<type>
<specifier>
public
</specifier>
<name>
void
</name>
</type>
<name>
testCompleteOption
</name>
<parameter_list>
( )
</parameter_list>
<block>
{
<block_content>
<decl_stmt>
<decl>
<type>
<name>
Option
</name>
</type>
<name>
simple
</name>
<init>
=
<expr>
<call>
<name>
<name>
OptionBuilder
</name>
<operator>
.
</operator>
<name>
withLongOpt
</name>
</name>
<argument_list>
(
<argument>
<expr>
<literal type="string">
"simple option"
</literal>
</expr>
</argument>
)
</argument_list>
</call>

Digging a little deeper into sequencing by analyzing the Abstract Syntax Tree of the test case...

```
/**
 *  1. Creates a new Option using OptionBuilder and checks its opt, long opt,
 *     description, type, arg, if its required and its args.
 */
@Test
public void testCompleteOption( ) {
    Option simple = OptionBuilder.withLongOpt( "simple option")
                                 .hasArg( )
                                 .isRequired( )
                                 .hasArgs( )
                                 .withType( Float.class )
                                 .withDescription( "this is a simple option" )
                                 .create( 's' );

    assertEquals( "s", simple.getOpt() );
    assertEquals( "simple option", simple.getLongOpt() );
    assertEquals( "this is a simple option", simple.getDescription() );
    assertEquals( simple.getType(), Float.class );
    assertTrue( simple.hasArg() );
    assertTrue( simple.isRequired() );
    assertTrue( simple.hasArgs() );
}
```

[OptionBuilder, withLongOpt, hasArg, isRequired, hasArgs, withType, withDescription, create]

[assertEquals, literal, typestrings, simple, getOpt, assertEquals, literal, typestrings, simple, getOpt, assertEquals, literal, typestrings, simple, getOpt, assertEquals, literal, typestrings, simple, getOpt, assertEquals, literal, typestrings, simple, getOpt, assertEquals, literal, typestrings, simple, getOpt, assertEquals, literal, typestrings, simple, getOpt]

...Sequencing of words/keywords, similar words and keywords, similar methods being called, similar assert statements.

Our Progress So Far...

- Identified key features of test case and test case scenario to use as fruitful data inputs for similarity models (scenario words, assert statements, invoked methods)
- Series of models identifying test cases with these similar key features have reduced the potential cluster group to 50% of the possible cluster group, with plenty of room for more growth through further experimentation

Conclusions

Impacts of this Research:

Auto-identified clusters through a light-weight prototype can help programmers to select which test cases to keep, integrate, or discard

Next Steps:

Continue working towards reducing False Positive rates by finding/tuning models to identify key features of similarity (similar wording, similar methods being tested, similar sequences of actions, etc) and continue creating the ‘series of experts’ prototype

Acknowledgements

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Thank You!!
...Questions?