Observation and Analysis

Projects executed with and without Ekstazi tool.

1. chukwa
2. closure-compiler
3. commons-coll4
4. commons-config
5. commons-lang3
6. commons-math
7. commons-pool
8. cucumber-jvm
9. gora
10. guava-libraries
11. zxing
12. tika
13. jgit
14. joda-time
15. log4j
16. netty
17. phoenix

From the data collected for above 17 projects from both Git and SVN across 20 revisions for without and with Ekstazi, we came across some interesting observations with respect to number of tests run and the total time of test case execution. The execution results can be viewed online at https://public.tableausoftware.com/views/SEv1/EmpiricalEvaluationOfEkstazi?:embed=y&:display_count=no.

Observations Without Ekstazi

1. The number of tests run fluctuated across different revisions of the same project. i.e. for revision 2 the number of tests run decreased when compared to revision 1.
2. The number of tests run constantly increased from one revision to the next.
3. For certain revisions, more time was taken to execute tests compared to the previous revision, although the number of test cases executed remained the same.
4. For some projects, no tests were executed. This was observed only for some revisions.

Observations With Ekstazi

1. The number of test cases run dropped to 0, compared to the tests run for the revision before. Ex. For Revision 1, the total number of tests were X, however in Revision 2, the tests run were completely reduced to 0.
2. Number of tests run between successive revisions remained 0 i.e. the technique of regression test selection was effective.

3. Time taken to reduce tests with Ekstazi was more compared to test execution without Ekstazi changes.
4.Test reduction was unusually low for some specific intermediate revisions.

To determine whether the above observations were indeed expected or dubious, we carried out thorough investigation on projects which showed the above anomalies. The result of the investigation is as below:

Analysis for various projects

1. Chukwa

project url: http://svn.apache.org/repos/asf/chukwa/trunk/

Without Ekstazi:

Observation-1:
For initial revision 1611855, the number of tests run (148) were more compared to the number of tests run(139 tests) in the next revision 1611856. **(Figure 1)**

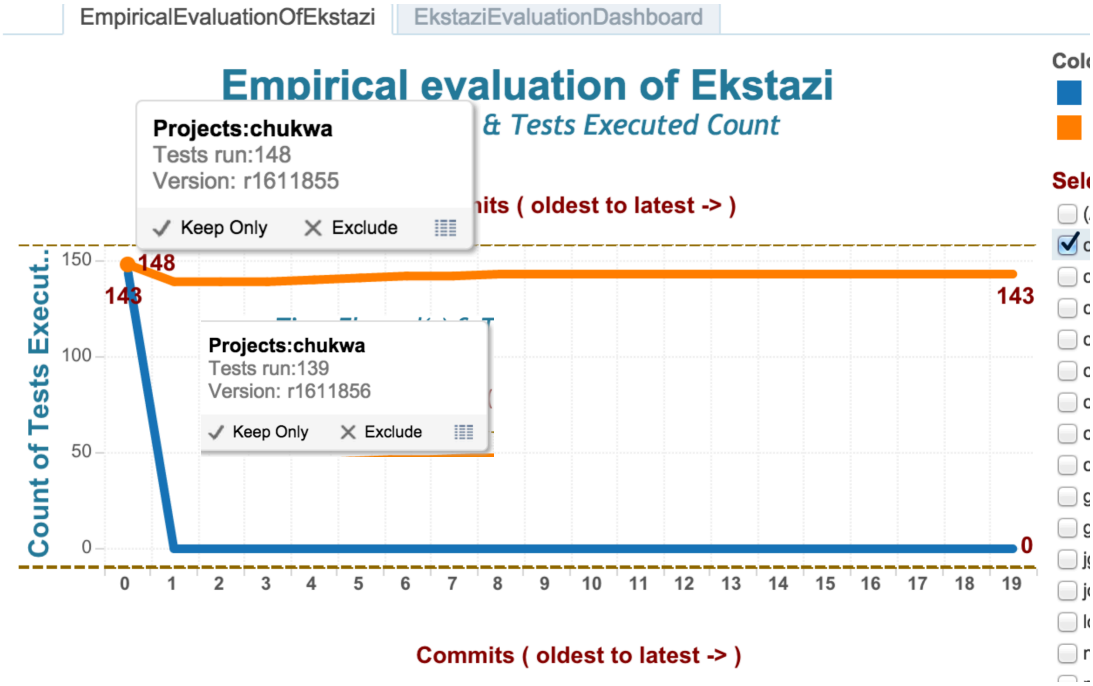

Figure 1

Reason:

To identify the reason for the above anomaly, we used the below svn command **svn diff -r 1611855:1611856**, which shows the differences between the two revisions mentioned. **(Figure 2)**

From the above result, we observed that in revision 1611856, total of 9 tests under file TestAdaptorController.java were removed as shown in Figure 2. Methods removed are testPrintNvp(), testPrintNvpIndented(), testPrintNvpIndentedWithDash(), testPrintNvpIndentedWithStringLiteral(), testPrintStartTag(), testPrintStartTagWithAttributes(), testPrintElement(), testPrintElementWithAttributes(), testPrintEndTag()

```
-  //  ** test utility methods **
-
-  public void testPrintNvp() throws IOException {
-    AdaptorController.appendNvp(sb, "foo", "bar");
-    assertEquals("Unexpected NVP", "foo: bar\n", sb.toString());
-  }
-
-  public void testPrintNvpIndented() throws IOException {
-    AdaptorController.appendNvp(sb, 4, "foo", "bar");
-    assertEquals("Unexpected NVP", "    foo: bar\n", sb.toString());
-  }
-
-  public void testPrintNvpIndentedWithDash() throws IOException {
-    AdaptorController.appendNvp(sb, 4, "- foo", "bar");
-    assertEquals("Unexpected NVP", "  - foo: bar\n", sb.toString());
-  }
-
-  public void testPrintNvpIndentedWithStringLiteral() throws IOException {
-    AdaptorController.appendNvp(sb, 4, "foo", "bar", true);
-    assertEquals("Unexpected NVP",
-            "    foo: |\n      bar\n", sb.toString());
-  }
-
-  public void testPrintStartTag() throws IOException {
-    AdaptorController.appendStartTag(sb, "Foo");
-    assertEquals("Unexpected XML", "<Foo>", sb.toString());
-  }
-
-  public void testPrintStartTagWithAttributes() throws IOException {
-    AdaptorController.appendStartTag(sb, "Foo", "a", "A", "b", "B <");
-    assertEquals("Unexpected XML",
-            "<Foo a=\"A\" b=\"B &lt;\">", sb.toString());
-  }
-
-  public void testPrintElement() throws IOException {
-    AdaptorController.appendElement(sb, "Foo", "Bar");
-    assertEquals("Unexpected XML", "<Foo>Bar</Foo>", sb.toString());
-  }
-
-  public void testPrintElementWithAttributes() throws IOException {
-    AdaptorController.appendElement(sb, "Foo", "Bar < -- />", "a", "A", "b", "B");
-    assertEquals("Unexpected XML",
-            "<Foo a=\"A\" b=\"B\">Bar &lt; -- /&gt;</Foo>", sb.toString());
-  }
-
-  public void testPrintEndTag() throws IOException {
```

Figure 2

Observation-2:
For revision r1612600 the total tests run were 139, however for next revison r1612604 the total tests run were 140. (Figure 3)

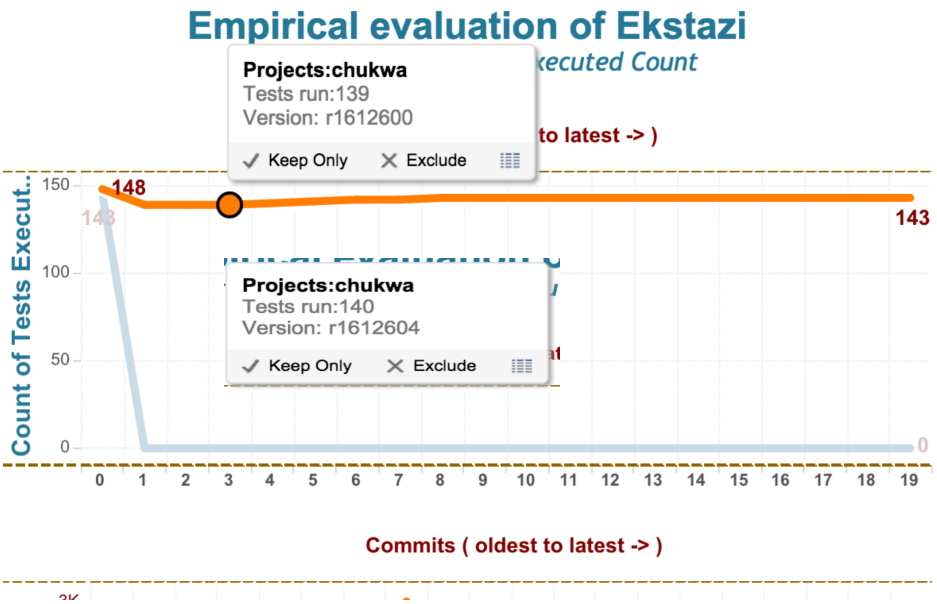

Figure 3

Reason:

Using svn diff between the above 2 revisions we found that a new test case was added to the file TestRestAdaptor.java. (Figure 4). This explains the increase of number of test executions by 1.

```
    CHUKWA-765. Updated Chukwa to support JDK7 and updated to Hadoop 1.2.1 and HBase 0.96.1.1.  (Eric Yang)
Index: src/test/java/org/apache/hadoop/chukwa/datacollection/adaptor/TestRestAdaptor.java
===================================================================
--- src/test/java/org/apache/hadoop/chukwa/datacollection/adaptor/TestRestAdaptor.java  (revision 0)
+++ src/test/java/org/apache/hadoop/chukwa/datacollection/adaptor/TestRestAdaptor.java  (revision 1612604)
@@ -0,0 +1,93 @@
+/*
+ * Licensed to the Apache Software Foundation (ASF) under one
+ * or more contributor license agreements.  See the NOTICE file
+ * distributed with this work for additional information
+ * regarding copyright ownership.  The ASF licenses this file
+ * to you under the Apache License, Version 2.0 (the
+ * "License"); you may not use this file except in compliance
+ * with the License.  You may obtain a copy of the License at
+ *
+ *     http://www.apache.org/licenses/LICENSE-2.0
+ *
+ * Unless required by applicable law or agreed to in writing, software
+ * distributed under the License is distributed on an "AS IS" BASIS,
+ * WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
+ * See the License for the specific language governing permissions and
+ * limitations under the License.
+ */
+package org.apache.hadoop.chukwa.datacollection.adaptor;
+
+import java.io.IOException;
+
+import javax.servlet.ServletException;
+import javax.servlet.http.HttpServlet;
+import javax.servlet.http.HttpServletRequest;
+import javax.servlet.http.HttpServletResponse;
+
+import junit.framework.TestCase;
+
+import org.apache.hadoop.chukwa.Chunk;
+import org.apache.hadoop.chukwa.datacollection.ChunkReceiver;
+import org.json.simple.JSONObject;
+import org.junit.After;
+import org.junit.Before;
+import org.junit.Test;
+import org.mortbay.jetty.Server;
+import org.mortbay.jetty.servlet.Context;
+import org.mortbay.jetty.servlet.ServletHolder;
+
+public class TestRestAdaptor extends TestCase implements ChunkReceiver {
```

Figure 4

With Ekstazi

Observation:
Ekstazi successfully reduced the number of tests run (142) from previous revision r1611855 to 0 tests run in the next revision r1611856. (Figure 5)

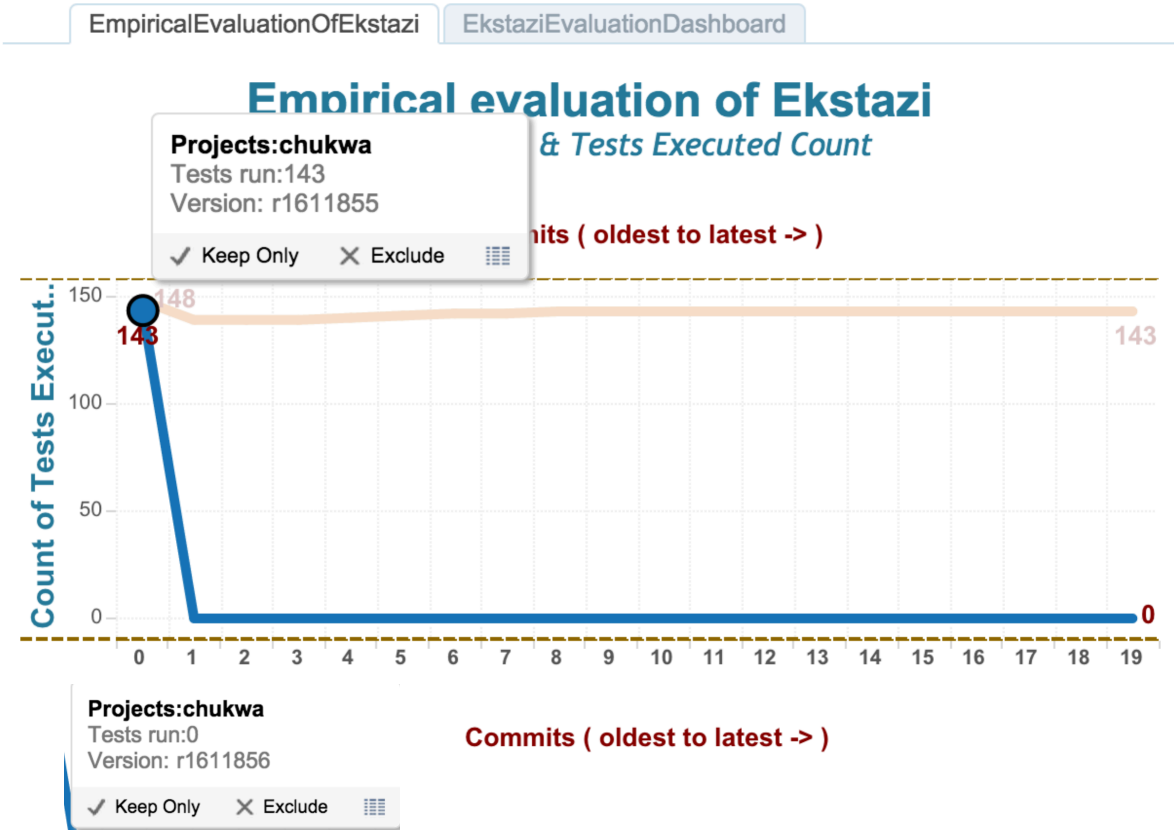

Figure 5

Reason:

To understand the change between the 2 revisions, we used the command
svn log -r 1611855:1611856 (Figure 6)

The above command gives the log message between the mentioned revisions.
Using the logs we observed that in revision 1611856, the log message was **"Updated Chukwa Agent REST API document and generation method"**
Since only the documentation was changed and no extra tests were added to the existing code, the tests were reduced to 0 as expected.

```
wirelessprvnat-172-17-56-137:chukwa suhas$ svn log -r 1611855:1611856
------------------------------------------------------------------------
r1611855 | eyang | 2014-07-19 02:24:44 -0500 (Sat, 19 Jul 2014) | 2 lines

CHUKWA-716. Fixed undefined System Properties for test cases and test case dependency.  (Eric Yang)

------------------------------------------------------------------------
r1611856 | eyang | 2014-07-19 03:06:33 -0500 (Sat, 19 Jul 2014) | 2 lines

CHUKWA-718. Updated Chukwa Agent REST API document and generation method.  (Eric Yang)

------------------------------------------------------------------------
```

Figure 6

2. Closure-Compiler

project url: https://github.com/google/closure-compiler

Without Ekstazi
Observation - 1:
There was increase in a test case execution from the revision 0fc234b to revision 21a2f2a (Figure 7)

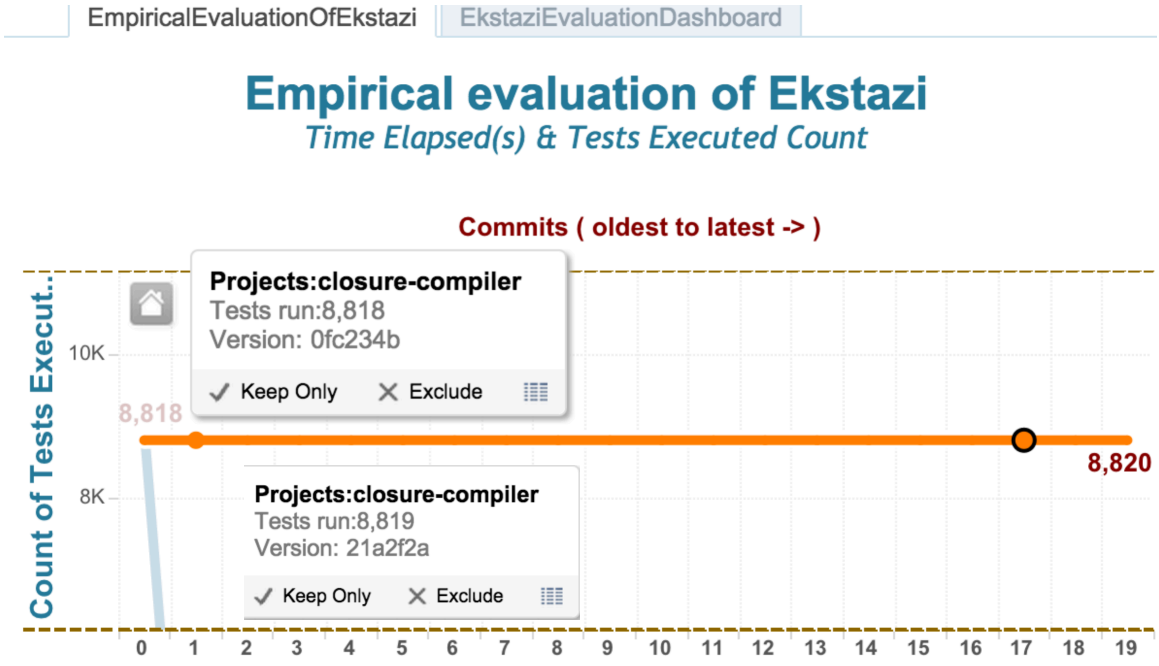

Figure 7

Reason:
we used **git diff 0fc234b 21a2f2a** to find the modifications between the two revisions.

From the above output, we observed that In file IntegrationTest.java a new test method named testSuppressBadGoogRequire() was added in the new revision (Figure 8). This explains the increase in a test case between the two revisions

```
index 9bc84a3..b7b7f5f 100644
--- a/test/com/google/javascript/jscomp/IntegrationTest.java
+++ b/test/com/google/javascript/jscomp/IntegrationTest.java
@@ -2372,6 +2372,19 @@ public class IntegrationTest extends IntegrationTestCase {
         "a.b.c.myFunc = function(x) {};");
   }

+  public void testSuppressBadGoogRequire() throws Exception {
+    CompilerOptions options = createCompilerOptions();
+    options.closurePass = true;
+    options.checkTypes = true;
+    test(
+        options,
+        "/** @suppress {closureDepMethodUsageChecks} */\n" +
+        "function f() { goog.require('foo'); }\n" +
+        "f();",
+        "function f() { goog.require('foo'); }\n" +
+        "f();");
+  }
+
```

Figure 8

Observation - 2:
The number of test cases executed between revisions 1bc2e0e and f02c5d2 were same

Reason:
Using **git diff 1bc2e0e f02c5d2**, we identified that there was no test cases added in the new revision. This is the result of same number of test case exections between the two revisions. (Figure 9)

```
commit f02c5d27c0f6f90b795299b9549154a334bf7c3d
Author: smckay <smckay@google.com>
Date:   Tue Nov 4 17:12:55 2014 -0800

    Add chrome.syncFileSystem to chrome_extensions.
    -------------
    Created by MOE: http://code.google.com/p/moe-java
    MOE_MIGRATED_REVID=79210534
```

Figure 9

With Ekstazi
Observation:
The number of tests run from first revision 6a1f2d7 to the next revision 0fc234b dropped to 0.

Reason:
Using git log -p -2, we observed that there was no new functionality added in the new revision 21a2f2a (Figure 10), and hence Ekstazi tool behaved as expected by reducing total number of tests run for this revision.

```
commit 0fc234b5fc10a7bb6545471f412ef99efe834149
Author: alusco <alusco@google.com>
Date:   Fri Oct 31 17:11:27 2014 -0700

    transition is a nullable promise on the $state object.
    -------------
    Created by MOE: http://code.google.com/p/moe-java
    MOE_MIGRATED_REVID=78969706

commit 6a1f2d75f5a211220deaff4660a997d4b8ebae75
Author: blickly <blickly@google.com>
Date:   Fri Oct 31 15:38:34 2014 -0700

    Fix handling of side-effects and short-circuiting in expressions containing yield expressions.

    Also introduce checks for cases where we wouldn't translate correctly and bail out.
    -------------
    Created by MOE: http://code.google.com/p/moe-java
    MOE_MIGRATED_REVID=78963231
```

Figure 10

3. Commons-Lang3
project url: http://svn.apache.org/repos/asf/commons/proper/lang/trunk

Without Ekstazi
Observation:
Between revisions 1632416 and r1632874, the number of tests executed was increased by 17. (Figure 11)

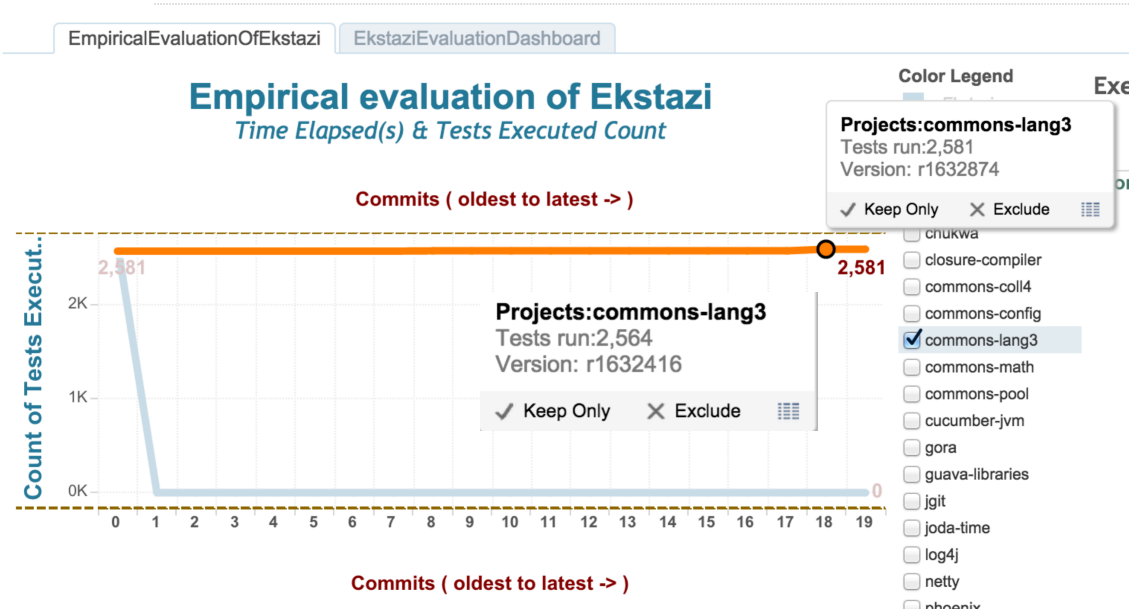

Figure 11

Reason:
svn diff -r r1632416:r1632874
When we analyzed the diff from the above two revisions, we observed that exactly 17 test cases (annotated with @Test) were added in the new revision 1632874 in the files ArrayUtilsTest.java, CharUtilsTest.java, BooleanUtilsTest.java and NumberUtilsTest.java (Figure 12).

```
Index: src/test/java/org/apache/commons/lang3/BooleanUtilsTest.java
===================================================================
--- src/test/java/org/apache/commons/lang3/BooleanUtilsTest.java        (revision 1632416)
+++ src/test/java/org/apache/commons/lang3/BooleanUtilsTest.java        (revision 1632874)
@@ -1006,5 +1006,13 @@
                     Boolean.TRUE })
                     .booleanValue());
     }
+
+    @Test
+    public void testCompare(){
+        assertTrue(BooleanUtils.compare(true, false) > 0);
+        assertTrue(BooleanUtils.compare(true, true) == 0);
+        assertTrue(BooleanUtils.compare(false, false) == 0);
+        assertTrue(BooleanUtils.compare(false, true) < 0);
+    }

 }
```

Figure 12

With Ekstazi
Observation:
Ekstazi reduced the number of tests run to 0 in both revisions 1630269 and 1630277. (Figure 13)

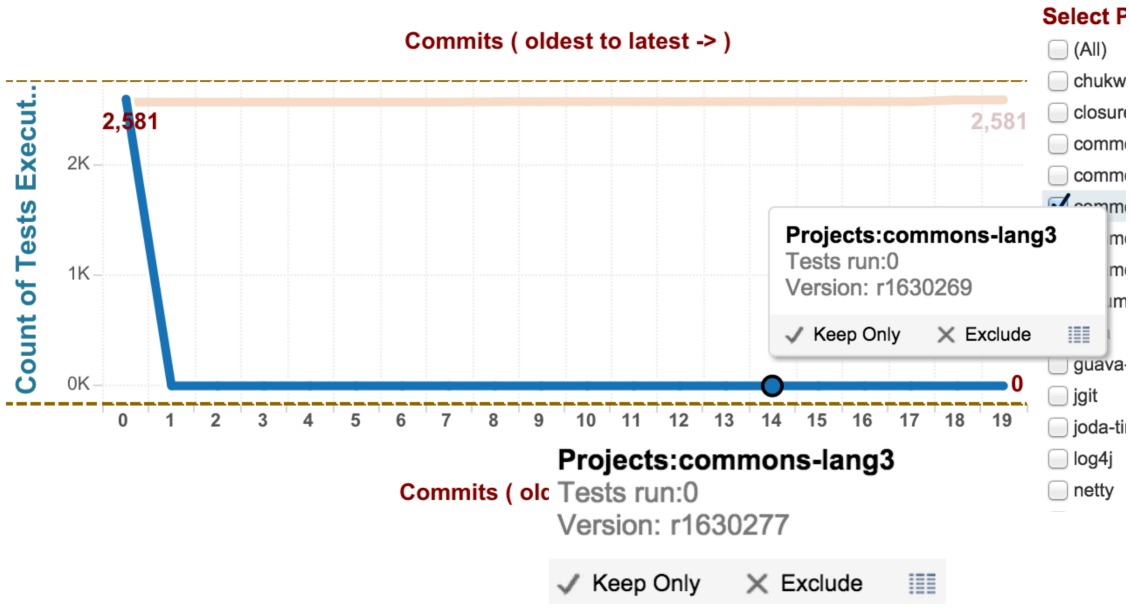

Figure 13

Reason:
svn diff -r r1630269:r1630277, this command revealed that there was no additional functionality added between the two revisions (Figure 14). The changes that was introduced were only contributor tag addition in pom.xml file and a comment addition in MethodUtils.java file. Thus, Ekstazi tool worked as expected by not running any test cases in the new revision.

```
Index: pom.xml
===================================================================
--- pom.xml     (revision 1632416)
+++ pom.xml     (revision 1632874)
@@ -374,6 +374,9 @@
       <name>Scott Sanders</name>
     </contributor>
     <contributor>
+      <name>James Sawle</name>
+    </contributor>
+    <contributor>
       <name>Ralph Schaer</name>
     </contributor>
     <contributor>
host-1-9:lang suhas$ open b
b.txt                   build.properties.sample  build.xml
host-1-9:lang suhas$ vi b.txt
host-1-9:lang suhas$ svn diff -r r1630269:r1630277
Index: src/main/java/org/apache/commons/lang3/reflect/MethodUtils.java
===================================================================
--- src/main/java/org/apache/commons/lang3/reflect/MethodUtils.java     (revision 1630269)
+++ src/main/java/org/apache/commons/lang3/reflect/MethodUtils.java     (revision 1630277)
@@ -191,6 +191,7 @@
      *
      * @param object invoke method on this object
      * @param methodName get method with this name
+     * @param args use these arguments - treat null as empty array
      * @return The value returned by the invoked method
      *
      * @throws NoSuchMethodException if there is no such accessible method
```

Figure 14

4. Commons-Config
project-url: http://svn.apache.org/repos/asf/commons/proper/configuration/trunk

With Ekstazi:
Observation:
Ekstazi tool reduced the number of tests cases run in revision 1629051, which is 2646 to 0 in revision 1629231.
Reason:
using the comand svn diff -r r1629051:r1629231, we identified that in the new revision 1629231, only a non functional change was introduced in site.xml file (Figure 15). Hence, as expected Ekstazi tool drastically reduced the number of tests run for this revision. Hence this case proves that Ekstazi tool is very effective RTS tool.

```
wirelessprvnat-172-17-56-137:config suhas$ svn diff -r r1629051:r1629231
Index: src/site/site.xml
===================================================================
--- src/site/site.xml   (revision 1629051)
+++ src/site/site.xml   (revision 1629231)
@@ -33,8 +33,8 @@
       <item name="Building"                    href="/building.html"/>
       <item name="Release History"             href="/changes-report.html"/>
       <item name="1.10" collapse="true"        href="/index.html">
-        <item name="User's Guide"              href="http://commons.apache.org/configuration/javadocs/v1.10/userguide/user_guide.html"/>
-        <item name="Javadoc"                  href="http://commons.apache.org/configuration/javadocs/v1.10/apidocs/index.html"/>
+        <item name="User's Guide"              href="/userguide_v1.10/user_guide.html"/>
+        <item name="Javadoc"                   href="http://commons.apache.org/configuration/javadocs/v1.10/apidocs/index.html"/>
         <item name="Runtime Dependencies"      href="/dependencies_1_10.html"/>
       </item>
       <item name="2.0-alpha" collapse="true"   href="/index.html">
```

Figure 15

5. Commons-Pool
project-url: http://svn.apache.org/repos/asf/commons/proper/pool/trunk

Without Ekstazi:
Observation:
For revision r1622424, the number of tests run were only 10 (Figure 16), whereas for the previous revision r1622092 the number of tests run was 256. This was strange as svn diff -r r1622092:r1622424 showed that 2 test cases were added. Hence, the number of tests run for this revision should have been 258 instead of 10.

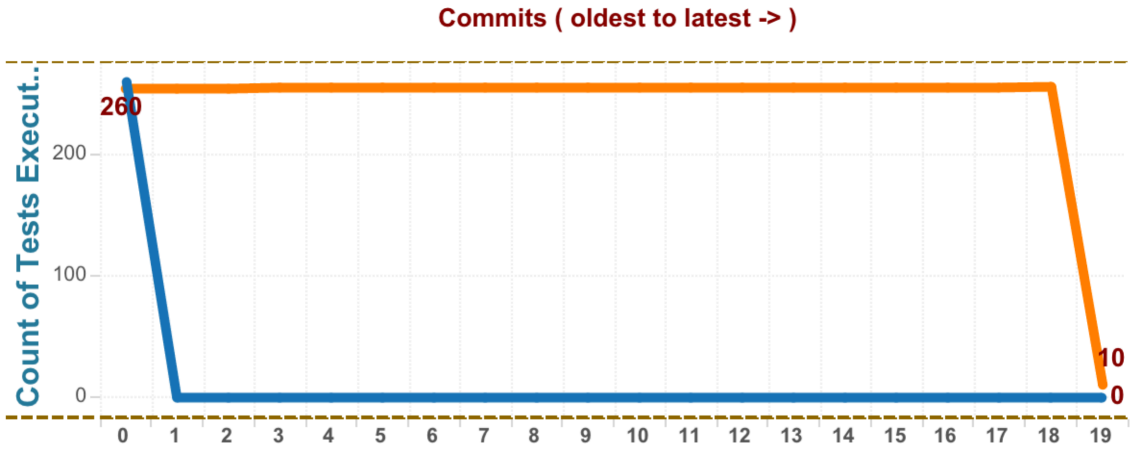

Figure 16

Reason:
When we executed mvn test for revision r1622424, initially there was a build failure after executing only 10 revisions and we got the below error:

[ERROR] Failed to execute goal org.apache.maven.plugins:maven-surefire-plugin:2.17:test (default-test) on project commons-pool2: There was a timeout or other error in the fork ->

Hence, we tried running only this revision in a different machine and observed that this time it ran successfully and the total number of test cases was 258 as expected. (Figure 17)

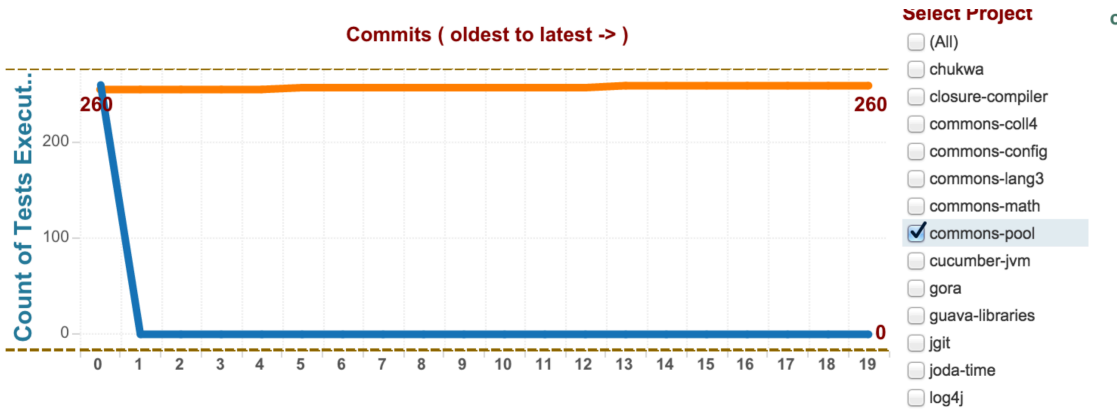

Figure 17

6. Joda-time, zxing

project-url:

https://github.com/JodaOrg/joda-time.git
https://github.com/zxing/zxing.git

Observation:

For both of the above projects, the time taken to reduce tests (with Ekstazi) was more compared to test execution without Ekstazi changes. (Figure 18)

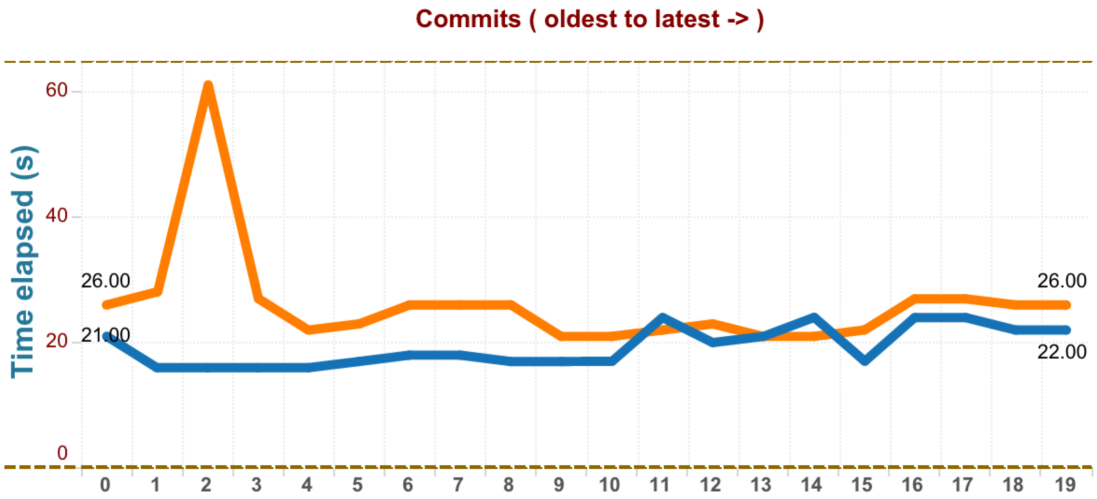

Figure 18

Reason:

To confirm whether this is a system issue, we ran the test for both joda-time and zxing with ekstazi again for 20 revisions on a different machine. This time, we also ensured that there are no other process running in parallel. On completion across 20 revisions, we observed that this time the time taken to reduce tests were significantly lower and matched the expectation of the tool. (Figure 19)

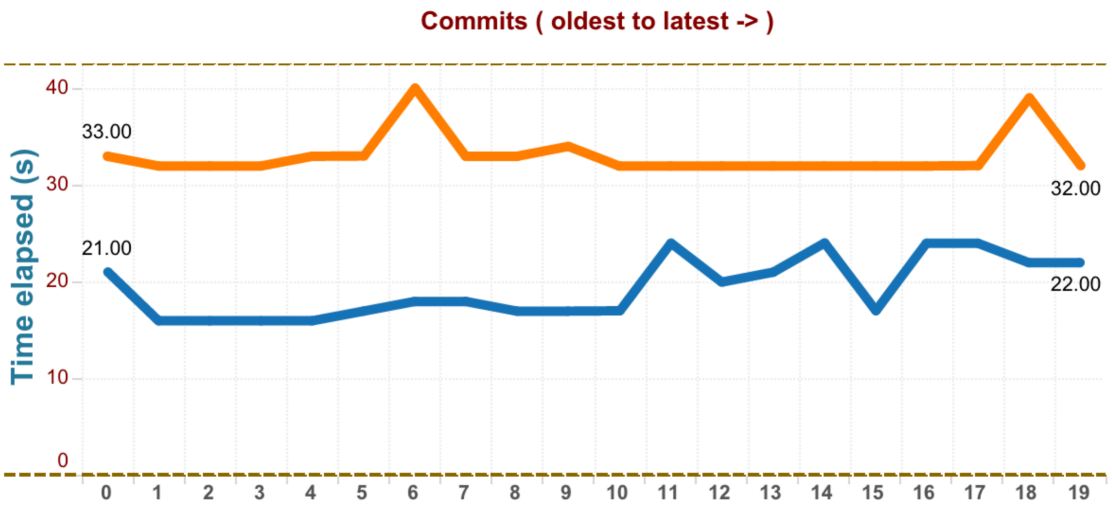

Figure 19

7. common-coll4, common-math, common-config, common-lang3

project-url:

http://svn.apache.org/repos/asf/commons/proper/collections/trunk,
http://svn.apache.org/repos/asf/commons/proper/math/trunk/
http://svn.apache.org/repos/asf/commons/proper/configuration/trunk
http://svn.apache.org/repos/asf/commons/proper/lang/trunk

Observation:
With Ekstazi changes, the number of tests reduced was unusually low for some specific intermediate revisions.

Reason:
The previous data had been collected for Ekstazi version 3.4.2. They were re excuted with Ekstzai version 4.2.0 (as with all other project runs). This time the reductions were as expected (no unsualy full test count selections for revisions were observed)

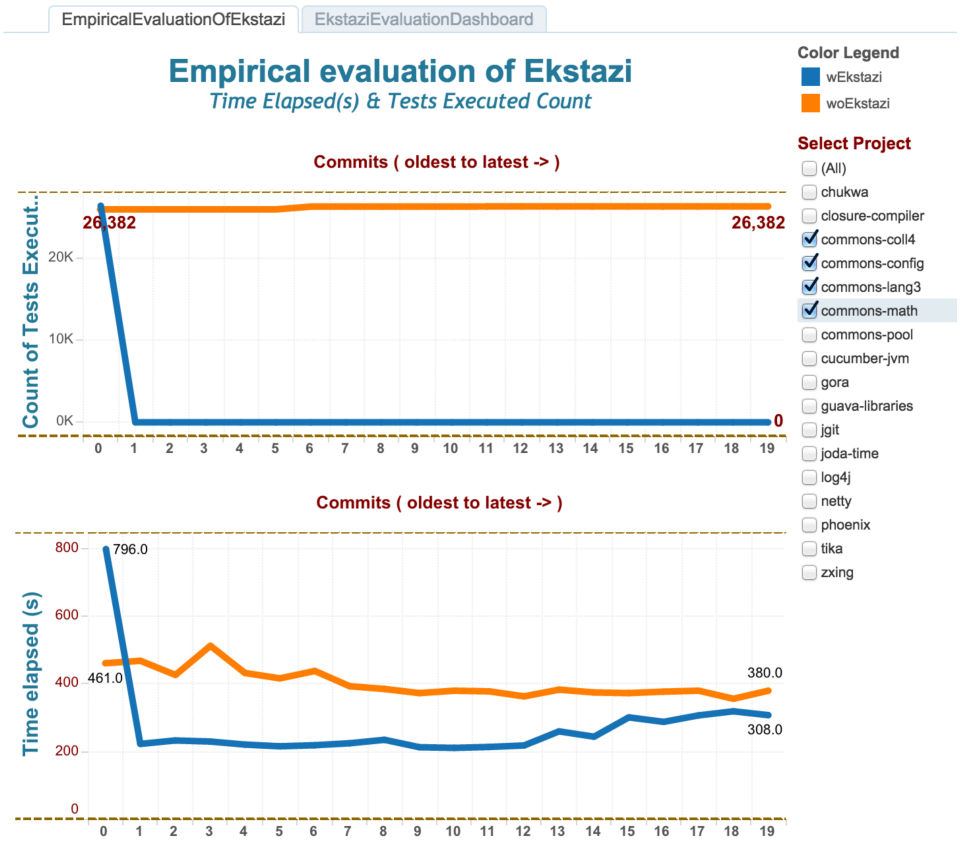

Figure 20

8. Gora
project-url: https://github.com/apache/gora.git

Observation:
Without Ekstazi:
There were random number of tests executed, sometimes number of tests run dropped to zero.
Example : r1560407 version had 0 tests executed [log at revision # -r3317 for the log logs/woEkstazi/gora_withoutEkstazi.log] because of below error

[ERROR] COMPILATION ERROR :
[INFO] --
[ERROR] /Users/suhas/Documents/prj/Computer_Science/curriculum/SE_UIUC/23Nov/newSVN/shmural2_srajend2/logs/repoDir/gora/gora-core/src/main/java/org/apache/gora/query/ws/impl/QueryWSBase.java:[24,29] error: package org.apache.gora.filter does not exist

Reason:
We tried re executing this project [revision # r3384 for the log logs/woEkstazi/gora_withoutEkstazi.log] but since its now moved to GIT from SVN,

we ran a fresh set of 20 revisions for both with and without Ekstazi. This time we see that there was no anomaly in the test result. (Figure 21)

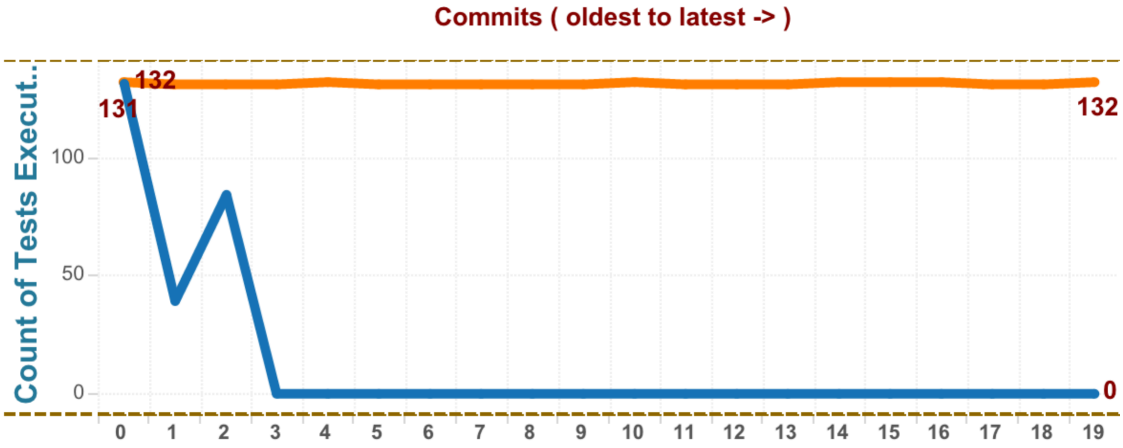

Figure 21

9. Phoenix
project-url: https://github.com/apache/phoenix
Observation:
For one revision a715a79, execution without ekstazi ran no tests. (Figure 22)

Figure 22

Reason:
After re executing this specific revision now, we found that build failed with below reason-

"Failed to execute goal org.apache.maven.plugins:maven-compiler-plugin:3.0:compile."

log can be found at logs/issues/phoenix_issue.log
This justified the reason for not running any test cases for that particular revision. However, after professor's suggestion, we re ran the tests for 20 revisions around that revision i.e. starting from revision de7c4df. This time all the tests executed successfully without any build failure. (Figure 23)

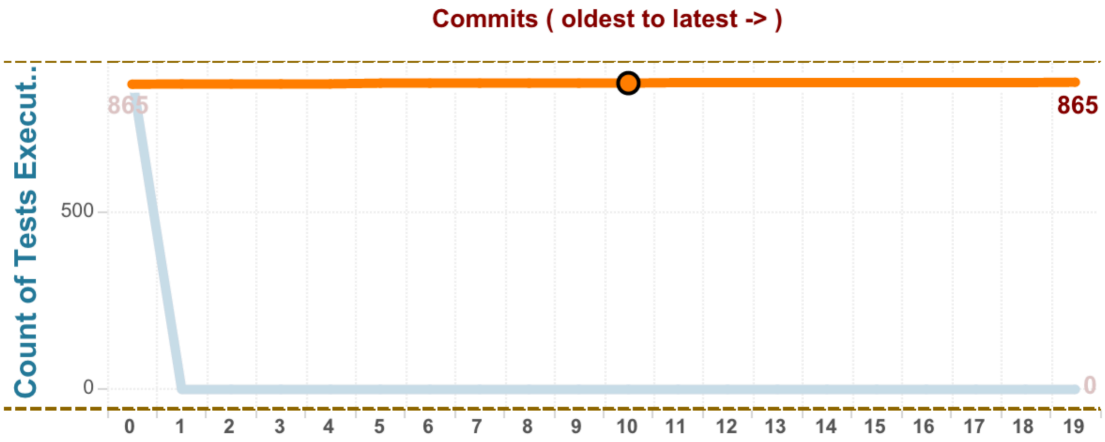

Figure 23

10. commons-lang3, commons-config
project-url:

http://svn.apache.org/repos/asf/commons/proper/configuration/trunk
http://svn.apache.org/repos/asf/commons/proper/lang/trunk

Observation:
The total time taken to execute tests with ekstazi for all the revisions was more compared to without ekstazi execution even though there was reduction in number of tests run. (Figure 24)

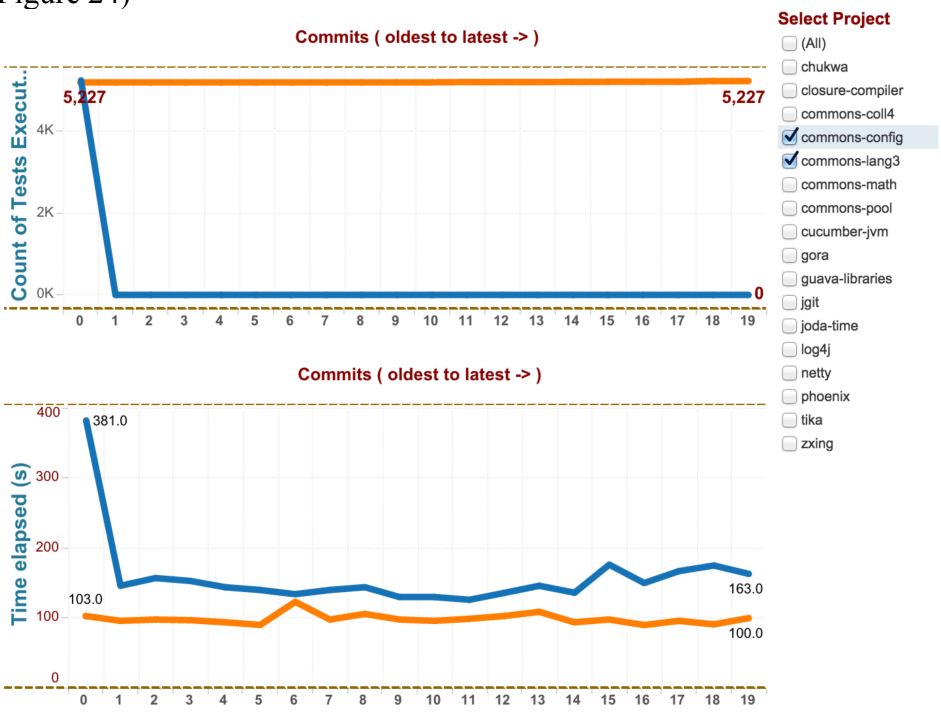

Figure 24

Reason:

To confirm whether this is a system issue, we ran the test for both commons-lang3 and commons-config with ekstazi again for 20 revisions on a different machine. This time, we also ensured that there are no other process running in parallel. On completion across 20 revisions, we observed that this time the time taken to reduce tests were significantly lower compared to that of without Ekstazi and matched the expectation of the tool. (Figure 25)

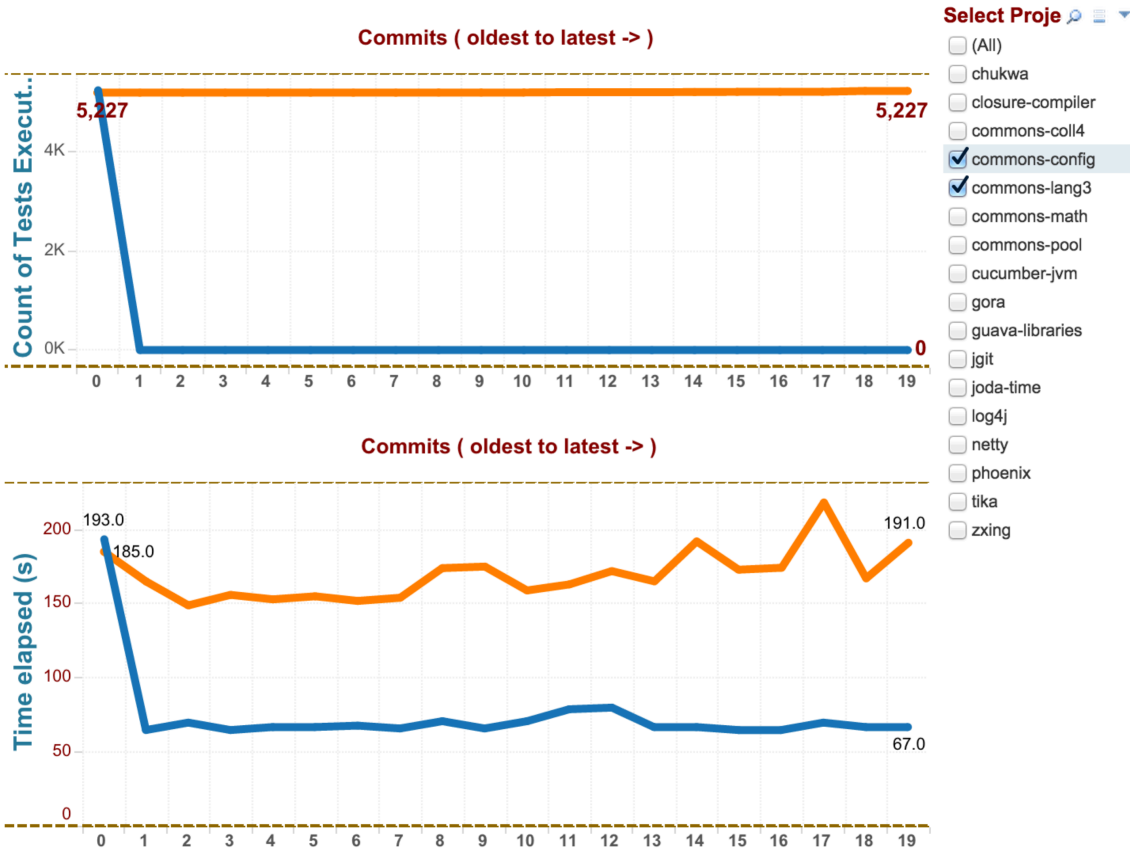

Figure 25