JTExpert at the Fourth Unit Testing Tool Competition

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ABSTRACT

JTExpert is a software testing tool that automatically generates a whole test suite to satisfy the branch-coverage criterion. It takes as inputs a Java source code and its dependencies and automatically produces a test-case suite in JUnit format. In this paper, we summarize our results for the Unit Testing Tool Competition held at the fourth SBST Contest, where JTExpert received 931 points and was ranked third. We also analyze our tool's performance.

Keywords

—Test-case generation; classes testing; unit testing; random testing; static analysis.

1. INTRODUCTION

This paper describes and discusses the results obtained by applying the test-case generation tool JTExpert [3] on the benchmarks used to compare tools participating in the unit-testing competition held as part of the International Workshop on Search Based Software Testing (SBST) held in Austin, TX, on May 16-17. More details on the competition and the benchmarks can be found elsewhere [2].

In this competition, JTExpert received a total score equal to 931 points and was ranked third. The total score sums up the scores of four experiments evaluating the participating tools using a given time budget: the 1^{st} uses 60 seconds, the 2^{nd} uses 120 seconds, the 3^{rd} uses 240 seconds, and the 4^{th} uses 480 seconds. JTExpert received 179.24 in the 1^{st} , 231.11 in the 2^{nd} , 250.92 in the 3^{rd} , and 269.73 in the 4^{th} .

2. JTEXPERT

JTExpert is a software testing tool that has been developed to automatically generate a whole test suite that satisfies the branch coverage criterion on a given Java source code [3]. Table 1 summarizes the main features of JTExpert. JTExpert automatically generates a JUnit test suite for the

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Table 1: Features of the tool JTExpert

Prerequisites					
Static or dynamic	Dynamic testing				
Software Type	Java source code (.java)				
Lifecycle phase	Unit testing for Java projects				
Environment	Java				
Knowledge required	JUnit				
Experience required	Unit-testing knowledge				
Input and Output of the Tool					
Input	A Java source code and its depen- dencies				
Output	A test-case suite in JUnit 4 format				
Operation					
Interaction	Through the command line				
Source of information	https://sites.google.com/site/saktiabdel/ JTExpert				
Maturity	Still under development				
Technology behind the tool	Random testing guided by static analyses				
Obtaining the tool and infor	mation				
License					
Cost	Free				
Support	None				
Empirical evidence about the Tool					
Effectiveness	See [3]				
Efficiency	See [3]				
Scalability	See [3]				

Class Under Test (CUT). It can be used through a command line interface. It takes as inputs a Java file (.java) and its dependencies and automatically produces a test-case suite in JUnit format. JTExpert is available as an executable Jar file. It is based on four main components: a source code analyzer, a test-case candidates builder, an instances generator, and a random search strategy.

2.1 Source Code Analyzer

JTExpert uses a Source Code Analyzer (SCA) to determine the set of methods that are likely to change the state of a data member of the CUT and the set of methods that may reach a given branch. The SCA analyzes the source code to collect constants and path information about all the branches of all methods. SCA provides JTExpert's other components with information to guide them throughout the process of test-case generation.

2.2 Test Case Candidates Builder

JTExpert uses the Test Case Candidates Builder (TDCB) to explore only relevant sequences of method calls. Using the collected information by SCA, the test-case generation problem is represented by a vector composed of means-of-

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instantiation of the CUT, methods that are likely to change the object state by changing a data member, and methods that may reach the branch target. Thus, JTExpert represents a test-case candidate by: (1) a means-of-instantiation of the class under test (i.e., a constructor, a method factory, a data field, or method external from the CUT); (2) a sequence of method calls whose length (i.e., number of method calls) is bounded by the number of declared data members in the CUT, each method in a sequence being called in the hope to put a given data member in a relevant state; (3) a method call that is likely to reach the test target; (4) a means-of-instantiation for each argument of the method.

The TDCB is a key novelty of JTExpert compared to other tools because it prevents JTExpert exploring useless sequences and thus to generate test cases faster without compromising coverage.

2.3 Instances Generator

JTExpert uses a customized instances generator based on a seeding strategy and a dynamic strategy to diversify generated instances of classes. The seeding strategy gets collected constants for each primitive data type or string and seeds them while generating instances. It defines a seeding probability of each data type according to the number of collected constants. Also, it seeds the null value with a constant probability while generating instances of classes. The diversification strategy generates different instances by using different means-of-instantiation (e.g., constructors, factory methods, subclasses).

The instances generator improves JTExpert exploration of the search space, reaching more branches, and thus increasing code coverage for a given time.

2.4 Random Search Strategy

JTExpert uses a random search that targets every uncovered branches at the same time: it does not focus on only one branch, instead it generates a test-case candidate uniformly at random for every uncovered branches. This strategy allows JTExpert to reach a good branch coverage quickly because it does not waste efforts on unreachable branches and it benefits from the significant number of branches that may be covered accidentally.

3. BENCHMARK RESULTS

Table 3 presents the results of JTExpert aggregated per benchmark. On average, JTExpert achieved 56.34% instructions coverage, 49.09% branch coverage, and 35.51% mutation coverage. These results are in line with our expectations except for classes where JTExpert gets 0% mutation coverage. In the following subsections, we highlight where our tool performed more poorly and provide possible explanations.

3.1 Compilation Errors

During the competition, JTExpert produced many uncompilable test-case files that significantly affected its performance. In all the experiments, JTExpert generated 37 uncompilable test-case files distributed as follow: 8 files during the first experiment; 7 files during the second experiment; 11 files during the third experiment, and 11 files during the fourth experiment. Each uncompilable test-case file received a score of 0 and -2 points as penalty. This problem specially affected four benchmarks: Chart-1, Chart-4,

Chart-26, and Math-44.

We analyzed these classes and observed that the first four classes are abstract and the problem relates to the way JT-Expert generates test cases for an abstract class. Actually, JTExpert instantiates an abstract class by using a possible stub and calls some methods from that stub. The problem was that, during the generation of source-code, we omitted to cast some variable from the abstract-class to the stub type.

3.2 Time Management

In the results file, we observed that for many CUTs JTExpert did not generate a test-case file. It could not generate 33 test-case files: 11 in the first experiment, nine in the second experiment, seven in the third experiment, and six in the fourth experiment. In general, JTExpert always generates a test-case file albeit an empty test-case file. We think that JTExpert generated test-case files for these CUTs but perhaps after the allowed time budget.

3.3 Low Branch Coverage

JTExpert achieved a weak branch coverage on the 16 benchmarks from the library Closure Compiler, com.google. javascript.jscomp. We analyzed the results of all tools and observed that this seems a general trend because all the participating tools have poor performances on this set of classes. The Closure Compiler is a JavaScript compiler and its classes includes a parser, lexical analyzer, and syntactical analyzer. In general, to instantiate such a type of class, a test-case generation tool must generate some strings that respect certain regular expressions and syntax. Because randomly generating such strings is almost impossible, a tool will fail to instantiate the CUT or the classes required to call its methods. Therefore, the low coverage achieved on classes from this library represents only the exceptions raised in constructors and public methods.

3.4 Mutation Coverage Measure

For many CUTs, the mutation coverage is very low compared to the code coverage. JTExpert generated a test-case file that reached more that 90% code coverage but, with 0% mutation coverage. For example, in the benchmark Lang-37 at the third experimentation (240s) and run number 5, the line coverage is equals to 94.67% with 0% mutation coverage. In Table 3, this problem is clear in the benchmarks Chart-1, Chart-12, and Chart-23 because it happened in all their test-case files. It also partially affected other benchmarks like Lang-36, Lang-41, and Lang-58 but it is not clear in the aggregated results. This problem affects 244 test-case suites generated by JTExpert.

During the set-up, we observed and mentioned a similar problem in Defect4j [1], the tool that measured the mutation coverage. Actually, if Defect4j cannot measure the mutation coverage for a test-case set, then it assigns a score of 0% of mutation coverage. We think that this measurement problem is at the root of some large differences between the code coverage and mutation coverage. Indeed, the organizers confirmed that this problem exists and affected 38 classes and around 1,024 test-case sets generated by different tools.

4. ANALYSIS AND DISCUSSIONS

Because of the abstract-classes bug, JTExpert produced 37 uncompilable test-case files that represent almost 2.5%

Table 2: DETAILED RESULTS OF JTExpert ON THE SBST-CONTEST BENCHMARKS WITH A TIME BUDGET EQUAL TO 240 SECONDS

International Control Partners	Banahmank	Class Name	Saana	FailTesta	Coverage			Total		
Lange3 args appele connous large trans. During Format/Table 17.8 22.3 0.75 0.09 329 137 269 Bigs 3 args appele connous large transmission formation for any state of the s	Benchmark	Class Name	Score	Faillests	Mutation	Branch	Line	Mutant	Branch	Line
Large 41 arg appele conversion and particular bits 21.4 [4.62] 0.6.8 0.0.9<	Lang-63	org. a pache. commons. lang. time. Duration Format Utils	37.83	2.33	0.73	0.96	0.99	329	133	229
Lacy, 30 org. papehe. connorms. langed Ches/This 10 0.0	Lang-41	org.apache.commons.lang.ClassUtils	32.74	4.62	0.56	0.86	0.91	346	216	268
Trace arg peda tuno have been dimensional per duration in the second per duration in the	Lang-33	org.apache.commons.lang3.ClassUtils	32.71	1.08	0.56	0.85	0.91	349	218	268
Adult 10 eric speake contrase, task is define. Normal-Determinating 2.8 2.7 1.0 0.0	Time-5	org.joda.time.Period	28.85	0.67	0.67	0.93	0.97	467	64	288
Statis 5 org spectra minimum support many many many many many many many many	Math-103	org.apache.commons.math.distribution.NormalDistributionImpl	28.56	2.42	0.46	0.67	0.76	108	116	42
adult product on analysis of the second se	Chart-11 Math 56	org. Jiree. chart. util. Shape Utilities	28.33	3.5	0.39	0.68	0.80	418	110	193
$ \begin{array}{c} Valth 2 \\ constraints in the list here in the list of the $	Math-50 Chort 16	org.apache.commons.math.util.MultidimensionalCounter	27.43	1.38	0.48	0.83	0.95	138	128	186
$ \begin{array}{c} \label{eq: constraints} \\ label{eq: co$	Moth 2	org anacha commons math? distribution HumorgoometriaDistribution	21.34	9.02	0.30	0.75	0.00	175	26	66
Tron. 13 org-plat.inc.former.PrivalFormiterFiniter 2004 428 00.83 0.38 0.39 1119 458 665 Lang 30 org.pache.commone.hang intel.NumberUbin 21.9 0.43 0.65 0.84 0.96 812 352 373 Lang 43 org.pache.commone.hang intel.NumberUbin 21.57 0.42 0.43 0.65 0.84 0.94 0.94 0.94 0.94 0.94 0.94 0.94 0.94 0.94 0.94 0.94 0.94 0.94 0.94 0.95 0.92 0.92 0.92 0.92 0.94 0.86 0.95 0.91 0.96 0.95 0.91 0.96 0.95 0.91 0.91 0.95 0.92 0.	Lang-57	org apache commons lang LocaleUtik	20.11	0.17	0.75	0.94	0.99	175	64	76
Lang-30 ore, space common lange text. StreichelbessegFormat 2457 35.12 0.02 0.04 0.05 0.12 0.02 0.04 0.05 0.12 0.02 0.04 0.05 0.14 0.05 0.14 0.05 0.14 0.05 0.14 0.05 0.14 0.05 0.14 0.05 0.14 0.05 0.14 0.05	Time-13	org ioda time format PeriodFormatterBuilder	26.22	4 29	0.50	0.81	0.93	1139	458	665
Lang-4 org-squebc commons lang test Stribuler 2473 3.12 0.28 0.41 0.55 184 09 103 Math-100 org-squebc commons math facton ProperVection Promat 23.06 0.67 0.58 0.66 0.78 4.62 046 700 0.48 0.81 0.84 0.85 0.84 0.85 0.84 0.85 0.84 0.85 0.84 0.85 0.85 0.84 0.85 0.84 0.85 0.84 0.85 0.85 0.84 0.85 0.84 0.85 0.84 0.85 0.84 0.85 0.84 0.85 0.84 0.85 0.84 0.85 0.84 0.85 0.84 0.85 0.84 0.85 0.84 0.85 <td>Lang-36</td> <td>org apache commons lang3 math NumberUtils</td> <td>25.04</td> <td>0.62</td> <td>0.43</td> <td>0.85</td> <td>0.96</td> <td>812</td> <td>352</td> <td>373</td>	Lang-36	org apache commons lang3 math NumberUtils	25.04	0.62	0.43	0.85	0.96	812	352	373
Lang-F org_squebc common sunt_forter Propertation Print 21.8 21.2 20.8 0.01 0.06 16.2 466 700 Lang-S org_squebc common sunt_finite Number Utin 22.30 0.22 0.22 0.30 0.06 0.78 40 19 63 106 107 10.8 106 17 20.8 108 106 22.0 10.2 0.77 0.42 0.78 0.01 108 116 20.0 Lang 65 org_squebc common sing time Farbitis 21.57 0.07 0.02 0.08 0.08 0.04 0.07 0.08 0.04 0.07 0.08 0.08 0.04 0.07 0.08 0.08 0.04 0.07 0.08 0.08 0.04 0.07 0.05 0.01 0.06 0.06 0.06 0.06 0.06 0.08 0.08 0.08 0.08 0.08 0.08 0.08 0.08 0.08 0.08 0.08 0.08 0.08 0.08 0.08 0.08 0.08	Lang-43	org.apache.commons.lang.text.ExtendedMessageFormat	24.73	3.12	0.20	0.43	0.55	184	99	163
Math-100 originable commons such fraction. Proper PractionProtein 23:50 0.67 0.07 0.08 0.06 0.78 0.46 0.19 0.53 Time-4 original commons lang time batch like 22:10 0.22 0.29 0.59 0.92 0.04 0.38 0.06 0.17 20.8 0.01 0.06 0.77 20.8 0.01 0.06 0.77 0.22 0.01 0.06 0.77 0.22 0.01 0.06 0.77 0.22 0.01 0.06 0.77 0.22 0.01 0.06 0.05 <	Lang-47	org.apache.commons.lang.text.StrBuilder	24.58	2.12	0.56	0.91	0.96	1642	496	700
Lang-Ss org-apache.common.hag.math.NumberUlin 22.70 0.42 0.19 0.84 0.94 0.97 420 0.83 0.92 0.94 0.95 0.92 0.94 0.95 0.92 0.94 0.95 0.92 0.94 0.95 0.92 0.94 0.95 0.92 0.94 0.95 0.92 0.94 0.95 <td>Math-106</td> <td>org.apache.commons.math.fraction.ProperFractionFormat</td> <td>23.96</td> <td>0.67</td> <td>0.30</td> <td>0.66</td> <td>0.78</td> <td>46</td> <td>19</td> <td>63</td>	Math-106	org.apache.commons.math.fraction.ProperFractionFormat	23.96	0.67	0.30	0.66	0.78	46	19	63
Time4 org job.time/Partial 12.27 0.29 0.29 0.29 0.39 0.91 336 106 210 Chart-7 org job.time/Particlylis 21.57 0.67 0.42 0.87 0.91 0.068 0.82 0.87 0.81 0.061 0.058 0.81 0.051 <td>Lang-58</td> <td>org.apache.commons.lang.math.NumberUtils</td> <td>22.79</td> <td>0.42</td> <td>0.49</td> <td>0.84</td> <td>0.94</td> <td>977</td> <td>420</td> <td>433</td>	Lang-58	org.apache.commons.lang.math.NumberUtils	22.79	0.42	0.49	0.84	0.94	977	420	433
Lang-60 org apache.commons.hang.tmm.Datel/Uils 21.27 0.67 0.42 0.78 0.91 406 175 208 Math-91 org.apache.commons.math.fraction.Praction 20.06 0.000 0.07 0.83 0.91 400 100 Char-7 org.[broc.that.ins.BrackSingle*feldPriod 20.21 0.000 0.000 0.050 0.84 0.91 400 100 0.000 0.050 0.84 0.91 108 244 666 Char-72 org.[broc.thr.104/W1Mather 116.56 0.021 0.046 0.056 0.041 0.056 0.041 0.057 0.91 11 8 22 138 200 Char-20 org.[broc.thr.104/W1Mather 15.59 0.021 0.048 0.71 0.77 2106 118 8 200 138 400 6 320 118 244 656 0.001 0.48 0.71 0.77 2106 120 233 300 0.01 130 0.91 143 400 430 121 140 400 140 400 140 <t< td=""><td>Time-4</td><td>org.joda.time.Partial</td><td>22.20</td><td>0.29</td><td>0.59</td><td>0.92</td><td>0.94</td><td>336</td><td>106</td><td>249</td></t<>	Time-4	org.joda.time.Partial	22.20	0.29	0.59	0.92	0.94	336	106	249
Chart-7 org.pfree.dat.rules numbersolvables 21.20 0.08 0.82 0.87 224 54 149 Math-91 org.pache.commons.math.fracton.Praction 20.65 0.08 0.88 0.84 138 46 70 Chart-21 org.phech.att-reducer GrayPaulisCole 19.53 0.09 0.88 0.84 0.84 0.87 0.83 0.84 0.84 0.84 0.84 0.84 0.84 0.85 0.84 0.84 0.85 0.84 0.85 0.84 0.85 0.84 0.85 0.84 0.85 0.85 0.84 0.85 0.84 0.75 0.91 0.85 0.84	Lang-65	org.apache.commons.lang.time.DateUtils	21.57	0.67	0.42	0.78	0.91	406	175	208
Math-9 org-apach.commos.math.fraction.Fraction 20.06 0.00 0.07 0.8.8 0.94 149 Chart-24 org.ploct.mic base.SensSingFeld/Period 2021 0.00 0.05 0.84 118 10 25 Chart-24 org.ploct.commoss.ling.time Fast Babte/privat 19.51 0.00 0.88 0.84 0.81 0.88 0.84 0.84 0.84 0.84 0.85 0.85 0.81 0.84 <t< td=""><td>Chart-7</td><td>org.jfree.data.time.TimePeriodValues</td><td>21.20</td><td>0.08</td><td>0.68</td><td>0.82</td><td>0.87</td><td>254</td><td>54</td><td>149</td></t<>	Chart-7	org.jfree.data.time.TimePeriodValues	21.20	0.08	0.68	0.82	0.87	254	54	149
Time 1 org.job.time.hane.BaseSingleFieldFedred 9021 0.00 0.05 </td <td>Math-91</td> <td>org.apache.commons.math.fraction.Fraction</td> <td>20.96</td> <td>0.00</td> <td>0.67</td> <td>0.83</td> <td>0.94</td> <td>360</td> <td>90</td> <td>149</td>	Math-91	org.apache.commons.math.fraction.Fraction	20.96	0.00	0.67	0.83	0.94	360	90	149
Chart-24 org fire-chart-mederer CorePaintScale 19.33 0.38 0.88 0.84 0.37 10 25 Lang-50 org apache.commons.lang.titen Fabruabeformat 19.38 0.66 0.83 0.93 0.93 1584 464 665 Lang-50 org apache.commons.lang.text StrBnikler 17.42 0.92 0.55 0.66 0.83 0.93 0.84 280 Chart-20 org firec.dat.in.in.Insertise 17.64 0.06 0.06 0.81 0.81 0.84 0.84 0.93	Time-10	org.joda.time.base.BaseSingleFieldPeriod	20.21	0.00	0.69	0.76	0.84	118	46	70
Lang-50 org apack.commons.lang text Strabulder 19.54 0.08 0.83 0.93 0.84 464 656 Chart-17 org fire-chart.phc ValueMarker 17.42 0.92 0.55 0.61 128 138 220 Lang-60 org apache.commons.lang Array ValueMarker 16.55 0.21 0.56 0.91 0.90 1384 464 656 Lang-60 org apache.commons.lang Array ValueMarker 16.55 0.01 0.91 0.97 2015 809 957 Maih-52 org apache.commons.lang Array ValueMarker 15.96 0.01 0.83 0.67 0.68 0.97 2016 128 207 Time-5 org joda.time.organtTimeZone 13.38 0.001 0.438 0.67 0.68 132 2010 0.418 0.77 533 132 203 0.431 0.83 0.82 228 255 Maih-38 org apache.commons.math.primizzion.linex?impleThabean 12.25 0.00 0.43 0.60 0.83 10.2	Chart-24	org.jfree.chart.renderer.GrayPaintScale	19.93	0.29	0.38	0.88	0.84	37	10	25
Laug-50 org. apache commons lang text StrBuilder 19.38 0.46 0.58 0.92 0.97 1584 464 656 Chart-1.70 org.free.dast.imb.TmsReries 17.42 0.92 0.55 0.91 11 8 220 Chart-2.00 org.apache.commons.lang.text.StrBuilder 16.56 0.01 0.48 0.71 0.706 122 3.77 Time-3 org.apache.commons.lang.text.StrBuilder 15.79 0.00 0.48 0.71 0.706 122 3.77 Time-3 org.joda.tim.Date TimeSome 13.83 0.00 0.44 0.77 2.706 122 3.77 Time-3 org.joda.tim.Charter TimeSome 13.83 0.00 0.41 0.65 0.77 4.33 102 2.80 103 104 12.83 104 0.83 102 2.80 103 104 12.83 104 0.83 102 2.80 103 104 12.83 104 12.83 104 13.83 100 0.41 13.8	Lang-50	org.apache.commons.lang.time.FastDateFormat	19.54	0.00	0.68	0.83	0.93	689	228	455
Chart-17 org.jprec.dat.jpred.th.jpred.th.alteMarker 17.42 0.25 0.55 0.61 428 138 282 Lang-60 org.apache.commonal.ang.tx1:stPuider 16.55 0.01 0.35 0.75 0.91 118 84 666 0.00 0.35 0.75 0.91 118 464 666 Math-22 org.apache.common.lang.ArrNV11is 115.07 0.00 0.03 0.81 0.91 0.93 0.77 0.53 0.91 0.93 0.77 0.53 162 235 Time-3 org.joch.time.DurfTimeZone 13.38 0.06 0.41 0.65 0.97 0.53 162 235 176 88 288 Math-84 org.apache.commons.math.31.imar.RectanglarCholesky Decomposition 12.25 0.00 0.32 0.77 0.66 192 299 131 84 90 134 55 1041 143 55 1041 144 146 56 104 144 56 1041 144 444 56 1041 145 56 1041 145 56 104 <td>Lang-59</td> <td>org.apache.commons.lang.text.StrBuilder</td> <td>19.38</td> <td>0.46</td> <td>0.58</td> <td>0.92</td> <td>0.97</td> <td>1584</td> <td>464</td> <td>656</td>	Lang-59	org.apache.commons.lang.text.StrBuilder	19.38	0.46	0.58	0.92	0.97	1584	464	656
Chart-30 org_itree chart jobt ValueMarker 16.66 0.00 0.45 0.75 0.59 11 18 22 Lang-60 org_apache commone.lang textStPuilder 16.55 0.21 0.56 0.91 0.54 0.64 666 Lang-57 org_apache.commone.lang textStPuilder 15.50 0.00 0.63 0.81 0.94 0.05 0.06 0.06 0.01 0.06 0.01	Chart-17	org.jfree.data.time.TimeSeries	17.42	0.92	0.25	0.55	0.61	428	138	280
Lang-37 org.apache.commons.langl.Ar.Array.Uils 16.55 0.21 0.56 0.91 0.59 1884 464 656 Math-52 org.apache.commons.langl.Array.Uils 15.79 0.00 0.63 0.81 0.94 122 327 Time-3 org.poch.time.Mutabe.Date TimeZone 14.84 0.012 0.23 0.87 0.88 0.93 1.82 304 Time-3 org.poch.time.DuteTimeZone 13.84 0.00 0.39 0.72 0.88 176 88 238 Time-7 org.poch.time.DuteTimeZone 13.84 0.00 0.39 0.72 0.88 176 88 238 Math-84 org.apache.commons.math.uil.Mathubliks 12.26 0.04 0.47 0.64 0.68 892 223 277 Time-20 org.plce.datime.format.DataTimeFormatterHulder 11.28 0.00 0.43 0.61 0.44 0.84 231 237 Time-2 org.free.dat.ime.format.DataTimeFormatterHulder 11.24 0.00 0.43	Chart-20	org.jfree.chart.plot.ValueMarker	16.66	0.00	0.45	0.75	0.91	11	8	22
Laug.37 org.apache.commons.math.geometry.eucliden.threed.Rotation 15.06 0.00 0.43 0.81 0.94 2015 806 957 Time-3 org.apache.commons.math.geometry.eucliden.threed.Rotation 15.06 0.00 0.48 0.71 0.77 2706 439 152 531 Time-3 org.joda.time.DatelTimeZone 13.88 0.08 0.08 0.03 0.77 3.53 162 338 Time-7 org.joda.time.forms.thatil.fineer.simplexTableau 12.85 0.00 0.44 0.05 0.07 0.83 162 934 Math-88 org.apache.commons.math.ditum.tectanguatCholeskyDecomposition 12.25 0.00 0.44 0.04 0.43 0.64 0.83 102 28 55 Math-30 org.apache.commons.math.ditum.tectanguatCholeskyDecomposition 11.25 0.00 0.43 0.61 143 490 144 149 144	Lang-60	org.apache.commons.lang.text.StrBuilder	16.55	0.21	0.56	0.91	0.96	1584	464	656
Math-32 org.apatch commons math.geometry ceirchean. Intreed. Actation 15.06 0.001 0.48 0.71 0.77 27.06 122 327 Time-8 org.jods.time. MatablabDate Time/Cone 13.88 0.018 0.028 0.027 0.56 0.90 0.53 231 Time-8 org.jods.time. Datel Time/Cone 13.28 0.00 0.39 0.72 0.88 1.76 8.8 208 Math-8 org.apache.commons.math.giun/Linkarto. 1.285 0.04 0.32 0.03 0.72 0.88 1.76 8.8 208 Math-21 org.apache.commons.math.giun/Linkarto. 1.285 0.04 0.47 0.80 0.83 1.02 2.8 55 Math-31 org.apache.commons.math.giun/Linkarto. 1.290 0.04 0.47 0.464 0.68 892 2.23 221 1.81 1.42 0.64 0.61 <td>Lang-37</td> <td>org.apache.commons.lang3.ArrayUtils</td> <td>15.79</td> <td>0.00</td> <td>0.63</td> <td>0.81</td> <td>0.94</td> <td>2015</td> <td>806</td> <td>957</td>	Lang-37	org.apache.commons.lang3.ArrayUtils	15.79	0.00	0.63	0.81	0.94	2015	806	957
Inne-3 org.jod.tit.mc.Nuttaber.Inter. 14.89 0.12 0.12 0.13 0.86 90 63 244 Time-3 org.jod.tit.mc.DateTimeZone 13.88 0.00 0.41 0.65 0.77 433 1162 338 Time-3 org.jod.tit.mc.DateTimeZone 13.35 0.00 0.41 0.66 0.77 0.58 176 68 302 90 131 Time-3 org.jod.tit.mc.DateTimeZone 13.35 0.00 0.24 0.80 0.88 102 28 55 Math-88 org.apache.commons.math.Journar.RetangularCholeskyDecomposition 12.55 0.00 0.41 0.66 0.88 102 28 55 Math-33 org.apache.commons.math.Journar.Inter.Inter.Retart.Retangular.Chart.Start	Math-52	org.apache.commons.math.geometry.euclidean.threed.Rotation	15.00	0.00	0.48	0.71	0.77	2706	122	327
Times Oig Johntinne Date TimeZone Tas.8 Outo O.38 Outo O.38 Outo O.39 Outo Tas.9 Outo Tas.9 Outo O.39 O.77 Tas.9 Out Tas.9 Outo O.39 O.77 O.88 Tas.9 Tas.9 Out O.39 O.72 O.88 Tas.9 Out Out <thout< th=""> <thout< th=""> Out</thout<></thout<>	Time-3	org.joda.time.MutableDate11me	14.89	0.12	0.23	0.87	0.80	90	100	247
Time-3 0ig_joda.inter.form introduce Tab. 25 0.00 0.01 0.03 0.71 0.53 102 28 Math-88 org_joda.inter.form anth.optimization.linear Simpler.Tublean 12.55 0.00 0.32 0.57 0.66 392 90 131 Math-84 org_apache.commons.math.dit.MathUtils 12.05 0.00 0.44 0.80 0.83 102 28 55 Math-33 org_apache.commons.math.attimeFormatterBuilder 11.98 0.00 0.43 0.70 0.80 1743 555 1034 Chart-3 org_jfore.chart.general.DatasetUtilitistul'UnivariateRealOptimizer 10.91 0.25 0.23 0.43 0.61 149 49 90 Chart-4 org_jfore.chart.general.DatasetUtilitistul'UnivariateRealOptimizer 10.16 0.00 0.28 0.51 0.58 74 548 808 Chart-6 org_jfore.chart.setogory.Abstract.Getogorthemeter 8.52 10.01 0.04 0.55 0.63 160 126 458 140 290	Time-8	org.joda.time.Date1imeZone	13.83	0.08	0.38	0.65	0.75	439	182	304
Time Org. apache. commons.math.optimization. linear Simples Tablean 12.85 0.00 0.32 0.12 0.83 110 83 200 Math-21 org. apache. commons.math.optimization. linear Simples Tablean 12.85 0.00 0.24 0.80 0.83 102 28 55 Math-23 org. apache. commons.math.optimization. linear Simples Tablean 12.20 0.04 0.47 0.64 0.68 892 223 227 Time-20 org. apache. commons.math.optimization.linear Simples Tablean 11.2 2.00 0.43 0.61 0.49 0.43 0.61 149 34 90 Chart-2 org. firee.dat.atime. TimeSeries 10.61 0.00 0.28 0.51 0.58 794 548 808 Chart-2 org. firee.dat.it.mlt.ShapeList 18.82 10.01 0.25 0.33 0.61 435 440 242 519 Chart-1 org. firee.dat.atime.TimeSeries 8.47 0.00 0.14 0.55 161 32 400 0.43	Time-25	org.joda.time.Date1imeZone	13.30	0.00	0.41	0.05	0.11	303	102	200
mathesis org-apacke commons.nath of minute metangular Cholesky Decay 131 Math-21 org-apacke commons.nath util. Math Utils 12.35 0.00 0.24 0.80 0.83 102 228 55 Math-33 org-apacke commons.nath util. Math Utils 12.20 0.04 0.47 0.64 0.68 892 223 227 Time-20 org-goda time format.Dact TimeFormatterBuilder 11.98 0.00 0.43 0.61 143 55 1034 Chart-23 org-gaeck commons.math.optimization.MultistartUnivariateRealOptimizer 10.91 0.25 0.23 0.43 0.61 149 34 90 Chart-3 org-free.data.time.TimeSeries 10.16 0.00 0.48 0.50 0.58 794 548 808 Chart-4 org-free.data.time.TimeSeries 10.16 0.00 0.18 0.50 0.50 28 16 34 Chart-4 org-free.data.time.TimeSeries 7.73 0.00 0.14 0.50 0.51 1613 276 467	Moth 88	org.joda.time.iormat.Date1imerormatter	13.20	0.00	0.39	0.72	0.00	202	00	121
Math-33 org-space commons.math.util.MathUtils Composition 12.20 0.04 0.47 0.64 0.68 892 223 227 Time-20 org-joal time format.DateTimeFormatterBuilder 11.32 0.04 0.47 0.64 0.68 892 223 221 Time-20 org-joed atime format.DateTimeFormatterBuilder 11.12 1.42 0.00 0.43 0.61 149 34 90 Chart-2 org-jfree.data-time.TimeSeries 10.77 0.00 0.40 0.66 0.76 490 194 371 Chart-3 org-jfree.data-time.TimeSeries 10.16 0.00 0.28 0.51 0.58 794 548 808 Chart-4 org-jfree.data-time.TimeSeries 8.47 10.40 0.02 5.03 0.61 435 140 220 Math-10 org-jfree.data-time.TimeSeries 8.47 10.40 0.06 0.65 1613 276 446 Math-20 org-apache commons.lang.Atcuntimeric.thtu/hu/bi/bi/bi/bi/bi/bi/bi/bi/bi/bi/bi/bi/bi/	Math-21	org anache commons math3 linear BectangularCholeskyDecomposition	12.65	0.04	0.32	0.57	0.00	102	28	55
Time-20 org.joda.time.format.DateTimeFormatterBuikler 11.98 0.00 0.43 0.70 0.80 17.32 595 1034 Chart-23 org.jence.hart.renderer.category.MinMaxCategoryRenderer 11.12 1.42 0.09 0.31 0.42 1.68 566 149 Chart-3 org.jfree.data.time.TimeSeries 10.01 0.25 0.23 0.04 0.66 174 90 Chart-4 org.jfree.data.time.TimeSeries 10.16 0.00 0.28 0.51 0.58 794 1548 808 Chart-4 org.jfree.data.time.TimeSeries 8.52 0.00 0.18 0.50 0.50 28 16 34 Chart-5 org.jerce.data.time.TimeSeries 8.47 0.04 0.26 0.53 0.61 10.13 276 6.40 Chart-5 org.apache.commons.math3.optimization.direct.CMAESOptimizer 7.73 0.00 0.14 0.32 0.65 1613 272 458 Chart-19 org.apache.commons.lang3.twhumericEntity Unseesper 6.33	Math-93	org apache commons math util MathIltils	12.00	0.00	0.47	0.64	0.68	892	20	227
Chart-23 org_ifree_chart.renderer.category.MinMaxCategoryRendeerr 11.12 1.42 0.09 0.31 0.42 168 56 149 Math-67 org_apache.commons.math.optimization.MultiStartUnivariateRealOptimizer 10.91 0.25 0.23 0.43 0.61 149 34 90 Chart-2 org_ifree.data.time.TimeSeries 10.77 0.00 0.40 0.66 0.76 490 194 371 Chart-2 org_ifree.data.time.TimeSeries 8.82 0.00 0.18 0.50 0.50 28 16 34 Chart-1 org_ifree.data.time.TimeSeries 8.47 0.04 0.26 0.53 0.61 435 140 280 Math-18 org_apache.commons.math3.optimization.direct.CMAESOptimizer 7.73 0.00 0.13 0.46 80 16 255 Lang-28 org_apache.commons.math3.optimization.direct.CMAESOptimizer 7.73 0.00 0.14 0.52 0.36 419 193 385 Closure-10 org_igod.tintite.ZoneInfo.Complet	Time-20	org.ioda.time.format.DateTimeFormatterBuilder	11.98	0.04	0.43	0.70	0.80	1743	595	1034
Math-67 org apache commons math optimization.MultiStartUnivariateRealOptimizer 10.91 0.25 0.23 0.43 0.61 149 34 90 Chart-3 org, jfree.data.time.TimeSeries 10.17 0.00 0.40 0.66 0.76 490 194 371 Chart-6 org, jfree.data.general.DatasetUilities 10.16 0.00 0.28 0.51 0.58 734 548 808 Chart-6 org, jfree.data.time.TimeSeries 8.52 1.03 0.07 0.25 0.33 246 242 519 Chart-1 org, apache.commons.math3.optimization. direct.CMAESOptimizer 7.73 0.00 0.14 0.50 0.65 1613 276 467 Math-80 org, apache.commons.math3.optimization.direct.CMAESOptimizer 7.63 0.00 0.13 0.48 0.65 1601 272 458 Lang.28 org.apache.commons.math3.optimization.direct.CMAESOptimizer 5.51 0.00 0.14 0.32 0.36 419 133 385 Closure-10	Chart-23	org.ifree.chart.renderer.category.MinMaxCategoryBenderer	11.12	1.42	0.09	0.31	0.42	168	56	149
Chart-3 org.jfree.data.time.TimeSeries 10.77 0.00 0.40 0.66 0.76 440 194 371 Chart-2 org.jfree.data.general.DatasetUtilities 10.16 0.00 0.28 0.51 0.58 794 548 808 Chart-1 org.jfree.dat.tructil.ShapeList 8.82 0.00 0.18 0.50 0.50 28 16 34 Chart-1 org.jfree.dat.tructineSeries 8.47 0.04 0.26 0.53 0.61 435 140 280 Math-18 org.apache.commons.math3.optimization.direct.CMAESOptimizer 7.73 0.00 0.14 0.50 0.65 1611 272 458 Lang-28 org.apache.commons.math3.optimization.direct.CMAESOptimizer 7.63 0.00 0.14 0.32 0.36 1601 272 458 Lang-28 org.apache.commons.lang3.text.translate.NumericEntityUnescaper 6.33 0.00 0.14 0.32 0.36 419 133 385 Chart-12 org.jfree.chart.pot.MultiplePieIot 4.57 0.04 0.10 0.41 0.52 164 84	Math-67	org.apache.commons.math.optimization.MultiStartUnivariateRealOptimizer	10.91	0.25	0.23	0.43	0.61	149	34	90
Chart-2 org.jfree.data.general.DatasetUilities 10.16 0.00 0.28 0.51 0.58 794 548 808 Chart-6 org.jfree.chart.renderer.category.AbstractCategoryItemRenderer 8.52 1.33 0.07 0.25 0.33 246 242 511 Chart-9 org.jfree.chart.renderer.category.AbstractCategoryItemRenderer 8.52 1.33 0.07 0.25 0.33 246 242 510 Math-18 org.apache.commons.math3.optimization.direct.CMAESOptimizer 7.73 0.00 0.14 0.55 1613 276 467 Math-20 org.apache.commons.math3.optimization.direct.CMAESOptimizer 7.63 0.00 0.13 0.48 0.65 1601 272 448 Lang-28 org.apache.commons.lang.stext.translate.NumericEntityUnescaper 6.53 0.00 0.14 0.52 0.36 419 193 385 Closure-98 com.google.javascript.jscomp.CheckGlobalThis 4.34 0.00 0.01 0.41 0.52 164 44 187 Closure-10 com.google.javascript.jscomp.CheckGlobalThis 4.44 0.00 0.07	Chart-3	org.jfree.data.time.TimeSeries	10.77	0.00	0.40	0.66	0.76	490	194	371
Chart-6 org.jfree.chart.util.ShapeList 8.82 0.00 0.18 0.50 0.50 228 16 34 Chart-1 org.jfree.chart.utine.TimeSeries 8.47 0.04 0.26 0.53 0.61 435 140 280 Math-18 org.apache.commons.math3.optimization.direct.CMAESOptimizer 7.73 0.00 0.14 0.50 0.65 1613 276 467 Math-20 org.apache.commons.math3.optimization.direct.CMAESOptimizer 7.63 0.00 0.14 0.50 0.65 1613 276 467 Lang-28 org.apache.commons.math3.optimization.direct.CMAESOptimizer 7.63 0.00 0.14 0.22 0.36 419 133 385 Closure-90 org.jfree.chart.plot.MultiplePiePlot 4.57 0.04 0.10 0.41 0.52 164 84 187 Closure-10 com.google.javascript.jcomp.CheckGlobalThis 4.04 0.00 0.07 0.17 0.42 112 62 45 Closure-14 com.google.javascript.jcomp.ControlFlowAnalysis 3.76 0.00 0.10 0.13 0.25	Chart-2	org.jfree.data.general.DatasetUtilities	10.16	0.00	0.28	0.51	0.58	794	548	808
Chart-1 org.jfree.dart.renderer.category.AbstractCategoryItemRenderer 8.52 1.33 0.07 0.25 0.33 246 242 519 Chart-9 org.jfree.dat.time.TimeSeries 8.47 0.04 0.26 0.53 0.61 435 140 280 Math-18 org.apache.commons.math3.optimization.direct.CMAESOptimizer 7.73 0.00 0.14 0.50 1613 276 467 Math-20 org.apache.commons.math3.optimization.direct.CMAESOptimizer 7.63 0.00 0.13 0.48 0.65 1610 272 458 Closure-98 corg.apache.commons.math3.optimization.direct.CMAESOptimizer 6.33 0.00 0.017 0.27 0.57 248 143 167 Time-11 org.jod.time.tz.ZoneInfoCompiler 5.51 0.00 0.14 0.32 164 84 187 Closure-100 com.google.javascript.jscomp.CheckGlobalThis 4.34 0.00 0.08 0.18 0.43 98 56 455 Closure-16 com.google.javascript.jscomp.CheckGlobalThis 4.34 0.00 0.07 0.17 0.42 112	Chart-6	org.jfree.chart.util.ShapeList	8.82	0.00	0.18	0.50	0.50	28	16	34
Chart-9 org.jfree.data.time.TimeSeries 8.47 0.04 0.26 0.53 0.61 435 140 280 Math-18 org.apache.commons.math3.optimization.direct.CMAESOptimizer 7.73 0.00 0.14 0.50 0.65 1613 276 467 Math-20 org.apache.commons.math3.optimization.direct.CMAESOptimizer 7.63 0.00 0.13 0.48 0.65 1601 272 458 Lang-28 org.apache.commons.math3.optimization.direct.CMAESOptimizer 6.36 0.00 0.017 0.27 0.57 248 143 167 Closure-98 com.google.javascript.jscomp.CheckGlobalThis 4.51 0.00 0.14 0.32 0.36 419 193 385 Closure-10 com.google.javascript.jscomp.CheckGlobalThis 4.54 0.00 0.00 0.41 0.52 166 454 Closure-14 com.google.javascript.jscomp.CheckGlobalThis 4.04 0.00 0.01 0.15 0.25 327 276 382 Closure-132 com.google.javascript.jscomp.PeepholeSubstituteAlternateSyntax 2.33 0.00 0.01 0.14	Chart-1	org.jfree.chart.renderer.category.AbstractCategoryItemRenderer	8.52	1.33	0.07	0.25	0.33	246	242	519
Math-18 org.apache.commons.math3.optimization.direct.CMAESOptimizer 7.73 0.00 0.14 0.50 0.65 1613 276 467 Math-20 org.apache.commons.math3.optimization.direct.CMAESOptimizer 7.63 0.00 0.13 0.48 0.65 1601 272 458 Lang-28 org.apache.commons.lang3.text.translate.NumericEntityUnescaper 6.36 0.00 0.017 0.27 0.57 248 143 167 Time-11 org.jackit.met.z.ZoneInfoCompiler 4.57 0.00 0.14 0.32 0.36 119 93 385 Closure-100 com.google.javascript.jscomp.CheckGlobalThis 4.57 0.04 0.10 0.41 0.52 164 48 187 Closure-10 com.google.javascript.jscomp.CheckGlobalThis 4.04 0.00 0.07 0.17 0.42 112 62 45 Closure-12 com.google.javascript.jscomp.PeopholeSubstituteAlternateSyntax 2.33 0.00 0.01 0.13 0.25 166 124 194 194 Closure-12 com.google.javascript.jscomp.PeopholeSubstituteAlternateSyntax 2.36	Chart-9	org.jfree.data.time.TimeSeries	8.47	0.04	0.26	0.53	0.61	435	140	280
Math-20 org.apache.commons.math3.optimization.direct.CMAESOptimizer 7.63 0.00 0.13 0.48 0.65 1601 272 458 Lang-28 org.apache.commons.lang3.text.translate.NumericEntityUnescaper 6.33 0.00 0.017 0.27 0.57 248 143 167 Closure-98 com.google.javascript.jscomp.ReferenceCollectingCallback 6.33 0.00 0.117 0.27 0.57 248 143 167 Closure-91 org.jfree.chart.plot.MultiplePiePlot 4.57 0.00 0.01 0.01 0.52 164 84 187 Closure-100 com.google.javascript.jscomp.CheckGlobalThis 4.34 0.00 0.007 0.17 0.42 112 62 45 Closure-16 com.google.javascript.jscomp.CheckGlobalThis 3.69 0.00 0.10 0.13 0.25 166 124 149 Closure-132 com.google.javascript.jscomp.PeepholeSubstituteAlternateSyntax 2.33 0.00 0.017 0.14 674 536 687 Closure-132 com.google.javascript.jscomp.PeepholeSubstituteAlternateSyntax 2.26 0.00 0.0	Math-18	org.apache.commons.math3.optimization.direct.CMAESOptimizer	7.73	0.00	0.14	0.50	0.65	1613	276	467
Lang-28 org.apache.commons.lang3.text.translate.NumericEntityUnescaper 6.36 0.00 0.08 0.40 0.46 80 16 25 Closure-98 com.google.javascript.jscomp.ReferenceCollectingCallback 6.33 0.00 0.17 0.27 0.57 248 143 167 Time-11 org.joda.time.tz.ZoneInfoCompiler 5.51 0.00 0.14 0.32 0.36 419 193 385 Chart-12 org.joda.time.tz.ZoneInfoCompiler 4.57 0.04 0.10 0.41 0.52 164 84 187 Closure-100 com.google.javascript.jscomp.CheckGlobalThis 4.34 0.00 0.07 0.17 0.42 112 62 45 Closure-16 com.google.javascript.jscomp.CheckGlobalThis 4.04 0.00 0.01 0.15 0.25 237 276 382 Closure-16 com.google.javascript.jscomp.PeepholeSubstituteAlternateSyntax 2.33 0.00 0.01 0.14 664 530 6867 Closure-10 com.google.javascript.jscomp.PeepholeSubstituteAlternateSyntax 2.26 0.00 0.01 0.01 0.1	Math-20	org.a pache.commons.math 3.optimization.direct.CMAESOptimizer	7.63	0.00	0.13	0.48	0.65	1601	272	458
Closure-98 com.google.javascript.jscomp.ReferenceCollectingCallback 6.33 0.00 0.17 0.27 0.57 248 143 167 Time-11 org.joda.time.tz.ZoneInfoCompiler 5.51 0.00 0.14 0.32 0.36 419 193 385 Chart-12 org.jfree.chart.plot.MultiplePiePlot 4.37 0.04 0.10 0.41 0.52 164 84 187 Closure-100 com.google.javascript.jscomp.CheckGlobalThis 4.34 0.00 0.07 0.17 0.42 112 62 45 Closure-16 com.google.javascript.jscomp.ControlFlowAnalysis 3.76 0.00 0.10 0.13 0.25 166 124 194 Closure-13 com.google.javascript.jscomp.PeepholeSubstituteAlternateSyntax 2.26 0.00 0.07 0.10 0.14 674 536 687 Closure-13 com.google.javascript.jscomp.PeepholeSubstituteAlternateSyntax 2.26 0.00 0.01 0.01 0.14 662 550 686 Math-39 org.apache.commons.math.ode.nonstiff.EmbeddedRungeKuttaIntegrator 1.28 0.00 0.01	Lang-28	org.a pache.commons.lang 3.text.translate.NumericEntityUnescaper	6.36	0.00	0.08	0.40	0.46	80	16	25
Time-11 org.joda.time.tz.Zonelni6Compiler 5.51 0.00 0.14 0.32 0.36 419 193 385 Chart-12 org.jfree.chart.plot.MultiplePieItot 4.57 0.04 0.10 0.41 0.52 164 84 187 Closure-100 com.google.javascript.jscomp.CheckGlobalThis 4.34 0.00 0.07 0.17 0.42 1112 62 45 Closure-16 com.google.javascript.jscomp.ControlFlowAnalysis 3.76 0.00 0.10 0.13 0.25 237 276 382 Closure-12 com.google.javascript.jscomp.PeepholeSubstituteAlternateSyntax 2.33 0.00 0.01 0.13 0.25 166 124 194 Closure-12 com.google.javascript.jscomp.PeepholeSubstituteAlternateSyntax 2.33 0.00 0.01 0.14 662 530 686 Math-39 org.apache.commons.math.ode.nonstiff.EmbeddedRungeKutattegrator 1.28 0.00 0.01 0.00 0.11 372 90 181 Closure-13 com.google.javascript.jscomp.PeepholeFoldConstants 0.71 0.00 0.01 0.03 <td< td=""><td>Closure-98</td><td>com.google.javascript.jscomp.ReferenceCollectingCallback</td><td>6.33</td><td>0.00</td><td>0.17</td><td>0.27</td><td>0.57</td><td>248</td><td>143</td><td>167</td></td<>	Closure-98	com.google.javascript.jscomp.ReferenceCollectingCallback	6.33	0.00	0.17	0.27	0.57	248	143	167
Chart-12 org, free,chart.plot.MultiplePiePlot 4.57 0.04 0.10 0.41 0.52 164 84 187 Closure-100 com.google.javascript.jscomp.CheckGlobalThis 4.34 0.00 0.08 0.18 0.43 98 56 455 Closure-99 com.google.javascript.jscomp.CheckGlobalThis 4.04 0.00 0.07 0.17 0.42 112 62 455 Closure-16 com.google.javascript.jscomp.ControlFlowAnalysis 3.76 0.00 0.10 0.13 0.25 166 124 194 Closure-132 com.google.javascript.jscomp.PeepholeSubstituteAlternateSyntax 2.23 0.00 0.07 0.10 0.14 662 530 686 Chart-25 org.apache.commons.math.ode.nonstiff.EmbeddedRungeKuttaIntegrator 1.28 0.00 0.01 0.00 0.30 279 54 108 Closure-14 com.google.javascript.jscomp.PeepholeSubstituteAlternateSyntax 0.71 0.00 0.01 0.07 0.11 372 90 181 Closure-74 com.google.javascript.jscomp.PeepholeFoldConstats 0.71 0.00 0.01<	Time-11	org.joda.time.tz.ZoneInfoCompiler	5.51	0.00	0.14	0.32	0.36	419	193	385
Closure-100 com.google_javascript_jscomp.CheckGlobalThis 4.34 0.00 0.08 0.18 0.43 98 56 45 Closure-190 com.google_javascript_jscomp.CheckGlobalThis 4.04 0.00 0.07 0.17 0.42 112 62 45 Closure-14 com.google_javascript_jscomp.ControlFlowAnalysis 3.76 0.00 0.01 0.13 0.25 127 276 382 Closure-132 com.google_javascript_jscomp.PeepholeSubstituteAlternateSyntax 2.33 0.00 0.07 0.10 0.14 674 536 687 Closure-20 com.google_javascript_jscomp.PeepholeSubstituteAlternateSyntax 2.26 0.00 0.01 0.01 0.14 662 530 686 Chat-25 org.jfree.chart.renderer.category.StatisticalBarRenderer 1.05 0.00 0.01 0.00 0.01 800 75 4 108 Chat-25 org.javascript_jscomp.PeepholeFoldConstants 0.71 0.00 0.01 0.03 0.07 880 624 765 Math-37 org.apache.commons.math.ode.nostiff.EmbeddedRungeKuttaIntegrator 0.69 <td< td=""><td>Chart-12</td><td>org.jfree.chart.plot.MultiplePiePlot</td><td>4.57</td><td>0.04</td><td>0.10</td><td>0.41</td><td>0.52</td><td>164</td><td>84</td><td>187</td></td<>	Chart-12	org.jfree.chart.plot.MultiplePiePlot	4.57	0.04	0.10	0.41	0.52	164	84	187
Closure-99 com.google.javascript.jscomp.CheckGlobalThis 4.04 0.00 0.07 0.17 0.42 112 62 45 Closure-14 com.google.javascript.jscomp.ControlFlowAnalysis 3.76 0.00 0.10 0.13 0.25 237 276 382 Closure-16 com.google.javascript.jscomp.ScopedAliases 3.69 0.00 0.10 0.13 0.25 166 124 194 Closure-132 com.google.javascript.jscomp.PeepholeSubstituteAlternateSyntax 2.33 0.00 0.07 0.10 0.14 662 530 687 Closure-132 org.gogle.javascript.jscomp.PeepholeSubstituteAlternateSyntax 2.26 0.00 0.01 0.00 0.01 614 662 530 6867 Closure-14 com.google.javascript.jscomp.PeepholeSubstituteAlternateSyntax 2.26 0.00 0.01 0.00 0.00 279 54 108 Chart-25 org.jfree.chart.renderer.category.StatisticalBarRenderer 1.05 0.00 0.01 0.03 0.07 880 624 765 Math-3 org.google.javascript.jscomp.CholpseProperties 0.52	Closure-100	com.google.javascript.jscomp.CheckGlobalThis	4.34	0.00	0.08	0.18	0.43	98	56	45
Closure-14 com.google.javascript.jscomp.Control fow Analysis 3.76 0.00 0.10 0.15 0.25 237 276 382 Closure-16 com.google.javascript.jscomp.ScopedAliases 3.69 0.00 0.10 0.13 0.25 166 124 194 Closure-132 com.google.javascript.jscomp.PeepholeSubstituteAlternateSyntax 2.33 0.00 0.07 0.10 0.14 662 530 686 Math-39 org.apache.commons.math.ode.nonstiff.EmbeddedRungeKuttaIntegrator 1.28 0.00 0.01 0.07 0.11 372 90 181 Closure-74 com.google.javascript.jscomp.PeepholeSubstituteAlternateSyntax 0.71 0.00 0.01 0.07 0.11 372 90 181 Closure-74 com.google.javascript.jscomp.PeepholeSoldConstants 0.71 0.00 0.01 0.03 0.07 358 266 330 Closure-130 com.google.javascript.jscomp.ExploitAssigns 0.52 0.00 0.00 0.01 0.04 73 68 74 Math-64 org.apache.commons.math.ode.AbstractIntegrator 0.02 0.00 <	Closure-99	com.google.javascript.jscomp.CheckGlobalThis	4.04	0.00	0.07	0.17	0.42	112	62	45
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Closure-132 com.google.javascript.jscomp.PeepholeSubstituteAlternateSyntax 2.33 0.00 0.07 0.10 0.14 674 536 686 Math-39 org.apache.commons.math.ode.nonstiff.EmbeddedRungeKuttaIntegrator 1.28 0.00 0.01 0.00 0.030 279 54 108 Chart-25 org.jfree.chart.renderer.category.StatisticalBarRenderer 1.05 0.00 0.01 0.07 0.11 372 90 181 Closure-74 com.google.javascript.jscomp.PeepholeFoldConstants 0.71 0.00 0.01 0.03 0.07 880 624 765 Math-7 org.apache.commons.math.3de.AbstractIntegrator 0.69 0.00 0.00 0.03 0.07 358 266 330 Closure-130 com.google.javascript.jscomp.CollapseProperties 0.52 0.00 0.00 0.03 0.07 358 266 330 Closure-124 com.google.javascript.jscomp.ExploitAssigns 0.48 0.00 0.01 0.04 73 68 74 Math-64 org.apache.commons.math.odt.AbstractIntegrator 0.00 0.00 0.00 0.00<	Closure-16	com.google.javascript.jscomp.ScopedAliases	3.69	0.00	0.10	0.13	0.25	166	124	194
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Consistence is consigned expendence on status 0.11 0.00 0.00 0.00 0.00 0.00 0.024 0.025 0.021 0.021 0.021 0.021 0.021 0.021 0.021 0.021 0.021 0.021 0.021 0.03 0.007 0.03 0.001 0.004 0.03 0.04 7.3 6.8 7.4 Math-64 org.apache.commons.math.optimization.general.LevenbergMarquardtOptimizer 0.00 0.	Closure-74	com google javascrint iscomp PeenholeFoldConstants	0.71	0.00	0.01	0.07	0.11	880	90 694	765
Instruct 0.5.07 0.607	Math-7	org apache commons math3 ode AbstractIntegrator	0.71	0.00	0.01	0.05	0.07	89	59	105
Closure 100 Comgoogle.javascript.jscomp.exploitAsgins 0.52 0.600 0.600 0.601 0.01 0.04 73 68 74 Math-64 org.apache.commons.math.optimization.general.LevenbergMarquardtOptimizer 0.20 0.00 0.00 0.00 0.00 1083 204 351 Math-64 org.apache.commons.math.optimization.general.LevenbergMarquardtOptimizer 0.20 0.00 0.00 0.00 0.05 1083 204 351 Math-64 org.apache.commons.math.ode.AbstractIntegrator 0.10 0.00 0.00 0.00 482 589 936 Closure-68 com.google.javascript.jscomp.parsing.JsDocInfoParser 0.00 1.00 0.00 0.00 482 589 936 Closure-46 com.google.javascript.hino.jstype.RecordType 0.00 1.00 0.00 0.00 482 589 936 Chart-4 org.jfree.chart.plot.XYPlot -2.17 0.12 0.01 0.03 0.05 1369 966 1749 Chart-26 org.jfree.chart.axis.Axis </td <td>Closure-130</td> <td>com google javascrint iscomp CollapseProperties</td> <td>0.09</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.22</td> <td>358</td> <td>266</td> <td>330</td>	Closure-130	com google javascrint iscomp CollapseProperties	0.09	0.00	0.00	0.00	0.22	358	266	330
Consistence 14* Consistenc	Closure-194	com google javascript jscomp Exploit Assigns	0.52	0.00	0.00	0.03	0.07	72	200	74
Math-4 org.apache.commons.math.openmated.betrafterence 0.00 <t< td=""><td>Math-64</td><td>org apache commons math optimization general Levenberg Marquardt Optimizer</td><td>0.40</td><td>0.00</td><td>0.01</td><td>0.01</td><td>0.04</td><td>1083</td><td>20/</td><td>351</td></t<>	Math-64	org apache commons math optimization general Levenberg Marquardt Optimizer	0.40	0.00	0.01	0.01	0.04	1083	20/	351
Closure-68 com.google.javascript.jscomp.parsing.JsDocInfoParser 0.00 0.00 0.00 0.00 0.00 482 589 936 Closure-64 com.google.javascript.rhino.jstype.RecordType 0.00 1.00 0.00 0.00 0.00 482 589 936 Closure-64 com.google.javascript.rhino.jstype.RecordType 0.00 1.00 0.00 0.00 58 72 88 Chart-4 org.jfree.chart.plot.XYPlot -2.17 0.12 0.01 0.03 0.05 1369 966 1749 Chart-26 org.jfree.chart.axis.Axis -5.38 0.00 0.00 0.00 3.00 3.78 136 329 Total/Average 931.01 35.51% 49.09% 56.34% 78.664 29.172 47.608	Math-44	org apache commons math ode AbstractIntegrator	0.20	0.00	0.00	0.00	0.00	79	204 46	120
Closure 46 com.google.javascript.rhino,istype.RecordType 0.00 0.00 0.00 0.00 462 369 360 Closure 46 com.google.javascript.rhino,istype.RecordType 0.00 1.00 0.00 0.00 58 72 88 Chart-4 org.jfree.chart.plot.XYPlot -2.17 0.12 0.01 0.03 0.05 1369 966 1749 Chart-26 org.jfree.chart.axis.Axis -5.38 0.00 0.00 0.00 378 136 329 Total/Average 931.01 35.51% 49.09% 56.34% 78.664 29.172 47.608	Closure-68	com google javascrint iscomp parsing JsDoeInfoParser	0.10	0.00	0.07	0.05	0.23	482	580	936
Chart-4 org.jfree.chart.plot.XYPlot -2.17 0.12 0.00 0.00 0.05 1369 966 1749 Chart-26 org.jfree.chart.axis.Axis -5.38 0.00 0.00 0.00 378 136 329 Total/Average	Closure-46	com.google.javascript.rhino.jstype.RecordType	0.00	1.00	0.00	0.00	0.00	-152	72	88
Chart-26 org.jfree.chart.axis.Axis Total/Average 931.01 35.51% 49.09% 56.34% 78.664 29.172 47.608	Chart-4	org.ifree.chart.plot.XYPlot	-2.17	0.12	0.01	0.03	0.05	1369	966	1749
Total/Average 931.01 35.51% 49.09% 56.34% 78.664 29.172 47.608	Chart-26	org.jfree.chart.axis.Axis	-5.38	0.00	0.00	0.00	0.00	378	136	329
		Total/Average	931.01		35.51%	49.09%	56.34%	78.664	29.172	47,608

 Table 3: Synthesis: the Results of all Tools

Metrics		JTExpert	Evosuite	T3	Randoop			
	#	88,068						
Line	Coverage	56.34 %	60.79~%	48.74~%	47.92 %			
	Rank	2	1	3	4			
	#	55,888						
Branch	Coverage	49.09 %	48.51 %	41.98 %	38.49%			
	Rank	1	2	3	4			
	#	144,660						
Mutant	Coverage	35.51 %	33.50 %	37.56~%	25.99 %			
	Rank	2	3	1	4			
Test Cases	#	76,407	88,531	194,193	14,013,583			
	Rank	1	2	3	4			
Uncompilable	#	37	13	0	5728			
	Rank	3	2	1	4			
Broken test	#	3,220	224	8,010	190,493			
	Rank	2	1	3	4			
Fail test	#	404	451	482	359			
rall test	Rank	3	2	1	4			
Time	# (h)	104.14	96.63	63.54	126.98			
	Rank	3	2	1	4			
	Line	166.43	181.54	128.74	129.85			
	Branch	284.31	309.37	224.81	201.65			
	Mutant	334.08	360.86	319.94	248.92			
Score Details	Fail	269.33	300.67	321.33	239.33			
	Penalty	-123.15	-25.79	-17.26	-72.81			
	Total	931.01	1126.65	977.57	746.95			
	Rank	3	1	2	4			

of the CUTs, 4% of the lines, 3% of the branches, and 2.5% of the mutants. Also, because of the time-management bug, JTExpert missed to generate 33 test-case files that represent 2% of the CUTs, 6% of the lines, 5.38% of the branches, and 2.7% of the mutants. Hat with standing, these bugs and with the smallest number of test cases, Table 3 shows that JTExpert outperformed the other tools in terms of branch-coverage criterion and it is ranked second in terms of line-coverage and mutation-coverage.

Table 3 presents a detailed comparison of the results of all participant tools. JTExpert performed better than Evosuite in terms of branch-coverage and mutation-coverage, whereas Evosuite got better scores than JTExpert in terms of these two criteria. This discrepancy could be explained by the way the score is computed. Indeed, the score assigned to a given class does not take in consideration the size of this class, i.e, a small class has the same weight as a large class. If we ignore the negative effects of the two bugs in JTExpert, then we can conclude that JTExpert outperforms Evosuite in large-size classes and Evosuite outperforms JTExpert in small-size classes.

JTExpert outperformed T3 in terms of line and branch coverage whereas T3 is better than JTExpert in terms of mutation coverage which could be explained by the number of test cases: JTExpert generated less than 40% of the number of test-cases generated by T3. It is well known that the number of test cases can significantly affects mutation coverage. The partial scores Line, Branch, and Mutant are in line with the code coverage, JTExpert outperformed T3, whereas T3 outperformed JTExpert in terms of Fail and Penalty metrics which could be explained by the time-management bug in JTExpert: the negative scores in penalty mainly come from the time required for test-cases generation. The metric Fail summarizes the number of actual errors each tool has revealed. To better understand the difference in terms of this metric between T3 and JTExpert, we analyzed in-depth this metric. Our analysis started at Table 3, where we observed that the benchmarks Closure-46 and Closure-68 have a value different to 0 in the FailTests column whereas the line

coverage equals to 0. This incompatible information leads us to ask, how does a test-case set that does not cover any line can reveal the actual errors? For those benchmarks, we found that JTExpert generated many empty test-case files (i.e., without any test case). Because an empty file systematically generates execution error, Defect4j wrongly considers that this file reveals an actual error. We think that this is a bug in Defect4j that could affect also others classes. Actually, Defect4j considers a test case to reveal an actual error if its execution fails on a buggy version of the CUT regardless the reason why it failed. Therefore, we conclude that any test case fails on the CUT may wrongly be considered as revealing actual errors. To confirm this conclusion, we randomly selected three test-case sets from Randoop results, one of them was generated for the benchmark Lang-59 and contains three test cases that fail on the CUT (i.e., toolName=randoop, timeBudget=60, benchmarkName=Lang-59, runId=1). Indeed, in the result log files, we found that instead of discarding these three test cases, Defect4j considered them able to reveal the actual errors in the buggy version of the CUT and assigned them 4 additional points in the scores. We reported this bug to the organizer who will consider it in next workshops.

This analysis showed that a bug in Defcet4j has affected the scores in terms of the Fail metric. We did not have enough time to analyze the other metrics, but we believe that the bug detected in Defect4j could also affect the mutation scores.

5. CONCLUSION

In this paper, we reported and analyzed the results obtained by JTExpert in the SBST Contest 2016. JTExpert performed well compared to its results in the SBST Contest 2015. However, the SBST Contest 2016 showed us different bugs and faults in JTExpert that must be tackled before the next SBST Contest. Also, our analysis of the results detected a bug in the contest platform that has affected the scores of the participant tools.

Actually, the SBST Contest 2016 offered a good opportunity to test some ideas that we partially implemented in JTExpert. We also learned, that the current version of JT-Expert still needs more efforts to become a mature and robust software-testing tool.

We thank the SBST Contest organizers for helping in enhancing our tools and identifying new research directions that will make JTExpert better.

6. REFERENCES

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