Appendix of "Mining Software Repair Models for Reasoning on the Search Space of Automated Program Fixing"

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Appendix of "Mining Software Repair Models for Reasoning on the Search Space of Automated Program Fixing" Technical report, INRIA

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This is the companion paper of "Mining Software Repair Models for Reasoning on the Search Space of Automated Program Fixing", accepted for publication in Empirical Software Engineering (Springer) on Sep. 11, 2013.

While the paper contains highlighted pieces of data, this document contains the whole data. The empirical results are computed from 62179 versioning transactions with at least one modified Java file of the repositories of Argouml, Columba, Jboss, Jhotdraw, Log4j, org.eclipse.ui.workbench, Struts, Carol, Dnsjava, Jedit, Junit, org.eclipse.jdt.core, Scarab and Tomcat [1].

1 Mathematical Formula for Computing the Median Number of Repair of MC-Shaper

Let's consider a set of N distinct repair actions $X_{i\in\{1,..,N\}}$. Each repair action has an occurrence probability p_i, ($\sum_i p_i = 1$) Let's define an "attempt" (drawing) consisting of n repair actions (one n-tuple, with the possibility that the some X_i are present more than once in the n-tuple, n is fixed. The question we pose is: *What is the median number of attempts for drawing a given n-tuple Y ?* The response is obtained as follows :

First, we are interested in the following probability:

- probability of drawing Y on the 1er attempt is $P_1(Y)$
- probability of drawing Y on the 2d attempt is $P_2(Y)$
- ..
- probability of drawing Y on the K attempt is $P_K(Y)$

Let's assume that we know p, the probability of drawing p with a single draw. Then we have $P_2(Y) = (1-p)p$ which means that we don't draw Y on the first attempt but we draw it on the second. The formula, for recurrence, is $P_k(y) = p(1-p)^{k-1}$ After k attempts, the probability of drawing Y is:

$$S_K(Y) = P_1(Y) + P_2(Y) + .. + P_K(Y)$$

$$S_K(Y) = \sum_{k=1}^{k=K} P_k(Y)$$

$$S_K(Y) = \sum_{k=1}^{k=K} p(1-p)^{k-1}.$$

The median number of attempts to draw Y is k^* such that $S_{k^*}(Y) \geq 0,5$. So, we calculate S_k iteratively stopping when that condition is accomplished.

p is the probability of drawing an ordered tuple with repetition. It is $p = x \times \times \Pi_i p(i)$, where x is the number of equivalent drawings. For ordered tuple with repetition, x is obtained with the multinomial theorem [2, p.73]:

$$x = \binom{n}{e_1, e_2, ..., e_m} = \frac{n!}{\Pi_{j=1}^{j=m}(e_j!)}$$

(e_j is the number of occurrences of element j inside Y and m the number of uniques elements in Y).

Finally,

$$p = \binom{n}{e_1, e_2, ..., e_m} \times \Pi_{r\in R} P_{\mathcal{P}}(r)$$

Let's illustrate with a concrete example: $N = 5, p_{X1} = 0,1, p_{X2} = 0,1, p_{X3} = 0,2, p_{X4} = 0,2, p_{X5} = 0,4$. To find $Y = (X1, X3, X5)$: $p = 6 \times 0,1 \times 0,2 \times 0,4$, and $S_k \geq 0.5$ for k = 15 attempts. To find $Y = (X1, X3, X3)$: $p = 3 \times 0,1 \times 0,2 \times 0,2$, and $S_k \geq 0.5$ for k = 58 attempts.

We gratefully thank Ph. Preux for his help in getting this formula right.

2 Empirical results

Table 1: The Frequency of Semantic Changes of Change Model CT Represented Among 62179 Versioning Transactions of Java Code.

Change Action	#changes.	Proba.
Statement_insert	345548	28,9
Statement_delete	276643	23,1
Statement_update	177063	14,8
Statement_parent_change	69425	5,8
Statement_ordering_change	56953	4,8
Additional_functionality	49192	4,1
Condition_expression_change	42702	3,6
Additional_object_state	29328	2,5
Removed_functionality	26172	2,2
Alternative_part_insert	20227	1,7
Alternative_part_delete	17197	1,4
Removed_object_state	16445	1,4
Parameter_insert	8609	0,7
Decreasing_accessibility_change	6772	0,6
Parameter_type_change	6683	0,6
Parameter_delete	6048	0,5
Method_renaming	4931	0,4
Attribute_renaming	4730	0,4
Increasing_accessibility_change	4562	0,4
Parameter_renaming	4296	0,4
Return_type_change	4029	0,3
Attribute_type_change	3474	0,3
Unclassified_change	1892	0,2
Parent_class_change	1829	0,2
Parameter_ordering_change	1606	0,1
Parent_interface_insert	1515	0,1
Parent_interface_delete	1189	0,1
Additional_class	1175	0,1
Removing_attribute_modifiability	1027	0,1
Adding_attribute_modifiability	916	0,1
Removed_class	682	0,1
Removing_method_overridability	603	0,1
Adding_method_overridability	548	0
Return_type_insert	491	0
Return_type_delete	444	0
Parent_class_insert	412	0
Parent_interface_change	411	0
Removing_class_derivability	303	0
Parent_class_delete	179	0
Adding_class_derivability	99	0
Class_renaming	35	0
Total	1196385	

Table 2: The Semantic Changes of Change Model CTET Represented Among 62179 Versioning Transactions of Java Code.

Change Action	#changes.	Proba.
Statement_insert of Method_invocation	83046	6,9
Statement_insert of If_statement	79166	6,6
Statement_update of Method_invocation	76023	6,4
Statement_delete of Method_invocation	65357	5,5
Statement_delete of If_statement	59336	5
Statement_insert of Variable_declaration_statement	54951	4,6
Statement_insert of Assignment	49222	4,1
Additional_functionality of Method	49192	4,1
Statement_delete of Variable_declaration_statement	44519	3,7

Statement_update of Variable_declaration_statement	41838	3,5
Statement_delete of Assignment	41281	3,5
Condition_expression_change of If_statement	40415	3,4
Statement_update of Assignment	34802	2,9
Additional_object_state of Attribute	29328	2,5
Removed_functionality of Method	26172	2,2
Statement_insert of Return_statement	24184	2
Statement_parent_change of Method_invocation	21010	1,8
Statement_delete of Return_statement	20880	1,7
Alternative_part_insert of Else_statement	20227	1,7
Alternative_part_delete of Else_statement	17197	1,4
Removed_object_state of Attribute	16445	1,4
Statement_update of Return_statement	15132	1,3
Statement_ordering_change of Method_invocation	14267	1,2
Statement_parent_change of If_statement	12399	1
Statement_insert of Switch_case	10927	0,9
Statement_parent_change of Assignment	9851	0,8
Statement_parent_change of Variable_declaration_statement	9818	0,8
Statement_parent_change of Return_statement	9160	0,8
Statement_delete of Switch_case	8787	0,7
Statement_ordering_change of Variable_declaration_statement	8740	0,7
Statement_insert of Catch_clause	8708	0,7
Statement_ordering_change of Break_statement	8685	0,7
Parameter_insert of Single_variable_declaration	8609	0,7
Statement_ordering_change of Switch_case	8383	0,7
Statement_delete of Catch_clause	7927	0,7
Statement_insert of Try_statement	7489	0,6
Statement_insert of For_statement	7109	0,6
Statement_ordering_change of Assignment	7084	0,6
Decreasing_accessibility_change of Modifier	6772	0,6
Statement_delete of Try_statement	6618	0,6
Statement_delete of For_statement	6407	0,5
Parameter_type_change of Simple_type	6167	0,5
Parameter_delete of Single_variable_declaration	6048	0,5
Statement_ordering_change of If_statement	5637	0,5
Statement_insert of Throw_statement	5519	0,5
Method_renaming of Method_declaration	4931	0,4
Statement_insert of Break_statement	4767	0,4
Attribute_renaming of Field_declaration	4730	0,4
Increasing_accessibility_change of Modifier	4562	0,4
Parameter_renaming of Single_variable_declaration	4296	0,4
Statement_delete of Throw_statement	3876	0,3
Return_type_change of Simple_type	3413	0,3
Statement_insert of While_statement	3253	0,3
Statement_delete of Break_statement	3234	0,3
Attribute_type_change of Simple_type	3063	0,3
Statement_delete of While_statement	2817	0,2
Statement_update of Throw_statement	2807	0,2
Statement_update of Super_constructor_invocation	2379	0,2
Statement_ordering_change of Return_statement	2168	0,2
Statement_parent_change of Break_statement	1921	0,2
Statement_insert of Switch_statement	1832	0,2
Parent_class_change of Simple_type	1829	0,2
Statement_update of Switch_case	1634	0,1
Parameter_ordering_change of Single_variable_declaration	1606	0,1
Statement_insert of Continue_statement	1597	0,1
Parent_interface_insert of Simple_type	1515	0,1
Condition_expression_change of For_statement	1407	0,1
Statement_delete of Switch_statement	1394	0,1
Unclassified_change of Modifier	1334	0,1
Statement_parent_change of For_statement	1295	0,1
Statement_parent_change of Continue_statement	1221	0,1
Parent_interface_delete of Simple_type	1189	0,1

Additional_class of Class	1175	0,1
Statement_delete of Continue_statement	1081	0,1
Removing_attribute_modifiability of Modifier	1027	0,1
Statement_delete of Super_constructor_invocation	1011	0,1
Statement_insert of Super_constructor_invocation	941	0,1
Adding_attribute_modifiability of Modifier	916	0,1
Condition_expression_change of While_statement	786	0,1
Removed_class of Class	682	0,1
Statement_insert of Synchronized_statement	666	0,1
Statement_parent_change of Try_statement	642	0,1
Statement_update of Class_instance_creation	623	0,1
Return_type_change of Primitive_type	615	0,1
Statement_insert of Super_method_invocation	607	0,1
Removing_method_overridability of Modifier	603	0,1
Statement_parent_change of Throw_statement	577	0
Adding_method_overridability of Modifier	548	0
Statement_parent_change of Switch_case	536	0
Statement_parent_change of While_statement	526	0
Parameter_type_change of Primitive_type	513	0
Statement_insert of Constructor_invocation	465	0
Statement_ordering_change of Catch_clause	458	0
Statement_delete of Class_instance_creation	454	0
Statement_update of Switch_statement	450	0
Statement_insert of Labeled_statement	432	0
Statement_ordering_change of For_statement	430	0
Statement_update of Catch_clause	426	0
Parent_class_insert of Simple_type	411	0
Attribute_type_change of Primitive_type	411	0
Parent_interface_change of Simple_type	411	0
Statement_delete of Synchronized_statement	403	0
Statement_insert of Class_instance_creation	394	0
Statement_delete of Super_method_invocation	344	0
Statement_delete of Labeled_statement	326	0
Removing_class_derivability of Modifier	303	0
Statement_ordering_change of Continue_statement	284	0
Statement_update of Super_method_invocation	280	0
Return_type_delete of Simple_type	277	0
Statement_delete of Constructor_invocation	277	0
Return_type_insert of Simple_type	276	0
Statement_ordering_change of Try_statement	276	0
Statement_update of Constructor_invocation	258	0
Return_type_insert of Primitive_type	213	0
Parent_class_delete of Simple_type	177	0
Statement_parent_change of Switch_statement	175	0
Statement_insert of Do_statement	171	0
Return_type_delete of Primitive_type	167	0
Statement_parent_change of Super_method_invocation	164	0
Statement_ordering_change of Throw_statement	161	0
Statement_update of Synchronized_statement	159	0
Statement_delete of Assert_statement	152	0
Statement_delete of Do_statement	146	0
Statement_ordering_change of While_statement	143	0
Statement_update of Break_statement	124	0
Statement_update of Labeled_statement	120	0
Unclassified_change of If_statement	119	0
Adding_class_derivability of Modifier	99	0
Statement_ordering_change of Super_method_invocation	95	0
Condition_expression_change of Do_statement	86	0
Unclassified_change of Variable_declaration_statement	86	0
Unclassified_change of Return_statement	84	0
Unclassified_change of Assignment	75	0
Statement_ordering_change of Switch_statement	67	0
Statement_insert of Assert_statement	59	0

Unclassified_change of Method_invocation	56	0
Statement_parent_change of Labeled_statement	48	0
Statement_insert of Enhanced_for_statement	43	0
Statement_parent_change of Synchronized_statement	41	0
Class_renaming of Type_declaration	35	0
Statement_ordering_change of Class_instance_creation	32	0
Unclassified_change of Else_statement	28	0
Statement_ordering_change of Synchronized_statement	27	0
Unclassified_change of Line_comment	23	0
Statement_parent_change of Do_statement	21	0
Statement_parent_change of Class_instance_creation	17	0
Statement_delete of Enhanced_for_statement	16	0
Unclassified_change of For_statement	16	0
Statement_ordering_change of Labeled_statement	12	0
Unclassified_change of Switch_case	11	0
Unclassified_change of Catch_clause	10	0
Unclassified_change of While_statement	10	0
Unclassified_change of Try_statement	10	0
Unclassified_change of Block_comment	9	0
Condition_expression_change of Enhanced_for_statement	8	0
Unclassified_change of Switch_statement	6	0
Statement_update of Continue_statement	6	0
Unclassified_change of Empty_statement	4	0
Unclassified_change of Postfix_expression	4	0
Statement_parent_change of Assert_statement	3	0
Parameter_type_change of Parameterized_type	3	0
Unclassified_change of Super_constructor_invocation	2	0
Statement_ordering_change of Enhanced_for_statement	2	0
Parent_class_delete of Parameterized_type	2	0
Statement_ordering_change of Do_statement	2	0
Unclassified_change of Break_statement	2	0
Statement_update of Assert_statement	2	0
Return_type_insert of Parameterized_type	2	0
Unclassified_change of Type_literal	1	0
Return_type_change of Parameterized_type	1	0
Parent_class_insert of Parameterized_type	1	0
Unclassified_change of Constructor_invocation	1	0
Unclassified_change of Throw_statement	1	0
Total	1196385	

Table 3: Spearman Correlation between the CT Change Action Probabilities of 14 Java Software Repositories. The majority is higher than 0.9, showing that the probability distribution over change actions is project-independent.

	dnsjava.cvs	columba	argouml	jboss	org.eclipse.jdt.core	org.eclipse.ui.workbench	tomcat.cvs	jEdit	struts.cvs	scarab	log4j.cvs	jhotdraw6	junit	carol
dnsjava.cvs	1.00	0.87	0.89	0.88	0.89	0.90	0.85	0.90	0.82	0.91	0.90	0.85	0.87	0.83
columba	0.87	1.00	0.94	0.91	0.85	0.91	0.84	0.88	0.91	0.92	0.90	0.91	0.85	0.88
argouml	0.89	0.94	1.00	0.95	0.89	0.94	0.85	0.90	0.87	0.93	0.94	0.90	0.85	0.92
jboss	0.88	0.91	0.95	1.00	0.91	0.96	0.84	0.90	0.87	0.92	0.97	0.87	0.86	0.94
org.eclipse.jdt.core	0.89	0.85	0.89	0.91	1.00	0.96	0.92	0.92	0.87	0.93	0.92	0.84	0.81	0.88
org.eclipse.ui.workbe	0.90	0.91	0.94	0.96	0.96	1.00	0.89	0.93	0.89	0.95	0.98	0.86	0.87	0.93
tomcat.cvs	0.85	0.84	0.85	0.84	0.92	0.89	1.00	0.90	0.83	0.89	0.87	0.87	0.83	0.80
jEdit	0.90	0.88	0.90	0.90	0.92	0.93	0.90	1.00	0.85	0.91	0.93	0.85	0.89	0.86
struts.cvs	0.82	0.91	0.87	0.87	0.87	0.89	0.83	0.85	1.00	0.90	0.87	0.83	0.81	0.88
scarab	0.91	0.92	0.93	0.92	0.93	0.95	0.89	0.91	0.90	1.00	0.94	0.88	0.87	0.90
log4j.cvs	0.90	0.90	0.94	0.97	0.92	0.98	0.87	0.93	0.87	0.94	1.00	0.86	0.91	0.93
jhotdraw6	0.85	0.91	0.90	0.87	0.84	0.86	0.87	0.85	0.83	0.88	0.86	1.00	0.85	0.84
junit	0.87	0.85	0.85	0.86	0.81	0.87	0.83	0.89	0.81	0.87	0.91	0.85	1.00	0.83
carol	0.83	0.88	0.92	0.94	0.88	0.93	0.80	0.86	0.88	0.90	0.93	0.84	0.83	1.00

Figure 1: The distribution of the ranking difference for the most correlated project pair (workbench&log4j, Spearman correlation of 0.98) and the least correlated project pair (Tomcat&Carol, Spearman correlation of 0.80) in change model CT. The project pair workbench&log4j has more change actions with distance lower than 5 (9 vs. 7), and project pairs Tomcat&Carol has more changes actions with rank distance greater than 15 (6 vs. 0). This explains the difference in the Spearman correlation values. Overall, the shape of the distribution is very similar.

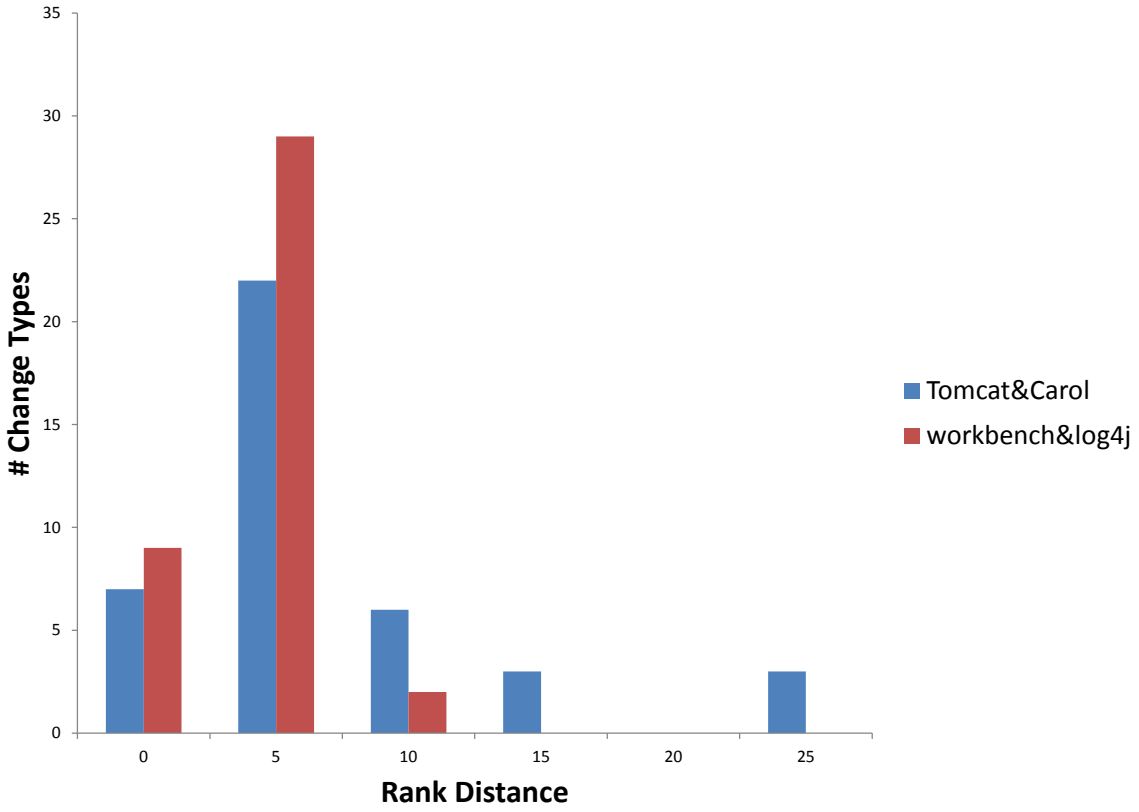

Table 4: Spearman Correlation between the CTET Change Action Probabilities of 14 Java Software Repositories. They are slightly lower than those of change model CT but the probability distribution over change actions can still be considered as project-independent.

	dnsjava	columba	argouml	jboss	eclipse.jdt.core	eclipse.ui.workbench	tomcat	jEdit	struts	scarab	log4j	jhotdraw6	junit	carol
dnsjava	1.00	0.84	0.83	0.89	0.86	0.87	0.88	0.87	0.84	0.85	0.87	0.79	0.73	0.83
columba	0.84	1.00	0.92	0.90	0.80	0.90	0.88	0.89	0.85	0.87	0.91	0.87	0.81	0.84
argouml	0.83	0.92	1.00	0.91	0.80	0.87	0.86	0.89	0.85	0.86	0.90	0.86	0.77	0.84
jboss	0.89	0.90	0.91	1.00	0.84	0.91	0.95	0.88	0.89	0.91	0.95	0.83	0.80	0.91
eclipse.jdt.core	0.86	0.80	0.80	0.84	1.00	0.83	0.87	0.89	0.81	0.78	0.86	0.73	0.64	0.73
eclipse.ui.workbench	0.87	0.90	0.87	0.91	0.83	1.00	0.91	0.89	0.82	0.89	0.91	0.84	0.76	0.83
tomcat	0.88	0.88	0.86	0.95	0.87	0.91	1.00	0.90	0.87	0.88	0.92	0.82	0.77	0.86
jEdit	0.87	0.89	0.89	0.88	0.89	0.89	0.90	1.00	0.85	0.85	0.89	0.80	0.73	0.79
struts	0.84	0.85	0.85	0.89	0.81	0.82	0.87	0.85	1.00	0.85	0.85	0.81	0.74	0.86
scarab	0.85	0.87	0.86	0.91	0.78	0.89	0.88	0.85	0.85	1.00	0.89	0.82	0.76	0.88
log4j	0.87	0.91	0.90	0.95	0.86	0.91	0.92	0.89	0.85	0.89	1.00	0.84	0.81	0.86
jhotdraw6	0.79	0.87	0.86	0.83	0.73	0.84	0.82	0.80	0.81	0.82	0.84	1.00	0.77	0.80
junit	0.73	0.81	0.77	0.80	0.64	0.76	0.77	0.73	0.74	0.76	0.81	0.77	1.00	0.78
carol	0.83	0.84	0.84	0.91	0.73	0.83	0.86	0.79	0.86	0.88	0.86	0.80	0.78	1.00

Table 5: CT Repair Actions and Probability χ_i for Different Heuristics to Build Versioning Transaction Bags.

Item	ALL	1-LC	1-SC	BFP	20-SC	20-LC
Statement_insert	0.2888	0.2446	0.1204	0.3211	0.3273	0.3417
Statement_delete	0.2312	0.1398	0.0635	0.2340	0.1624	0.1776
Statement_update	0.1480	0.3336	0.3825	0.1213	0.1596	0.1514
Statement_parent_change	0.0580	0.0627	0.0090	0.0664	0.0719	0.0986
Statement_ordering_change	0.0476	0.0178	0.0170	0.0592	0.0286	0.0458
Additional_functionality	0.0411	0.0013	0.1381	0.0407	0.0669	0.0210
Condition_expression_change	0.0357	0.1254	0.1282	0.0291	0.0466	0.0551
Additional_object_state	0.0245	0.0072	0.0253	0.0245	0.0299	0.0156
Removed_functionality	0.0219	0.0021	0.0451	0.0167	0.0222	0.0070
Alternative_part_insert	0.0169	0.0052	0.0000	0.0194	0.0171	0.0220
Alternative_part_delete	0.0144	0.0054	0.0000	0.0150	0.0095	0.0131
Removed_object_state	0.0137	0.0077	0.0165	0.0114	0.0116	0.0071
Parameter_insert	0.0072	0.0018	0.0007	0.0065	0.0053	0.0050
Decreasing_accessibility_change	0.0057	0.0057	0.0071	0.0039	0.0048	0.0038
Parameter_type_change	0.0056	0.0031	0.0040	0.0026	0.0030	0.0040
Parameter_delete	0.0051	0.0008	0.0000	0.0037	0.0026	0.0022
Method_renaming	0.0041	0.0021	0.0021	0.0027	0.0030	0.0023
Attribute_renaming	0.0040	0.0008	0.0012	0.0026	0.0029	0.0022
Increasing_accessibility_change	0.0038	0.0124	0.0137	0.0031	0.0059	0.0086
Parameter_renaming	0.0036	0.0010	0.0009	0.0020	0.0023	0.0020
Return_type_change	0.0034	0.0013	0.0014	0.0015	0.0019	0.0018
Attribute_type_change	0.0029	0.0021	0.0019	0.0014	0.0023	0.0022
Unclassified_change	0.0016	0.0013	0.0019	0.0020	0.0010	0.0020
Parent_class_change	0.0015	0.0026	0.0024	0.0014	0.0016	0.0009
Parent_interface_insert	0.0013	0.0041	0.0045	0.0009	0.0017	0.0011
Parameter_ordering_change	0.0013	0.0000	0.0000	0.0009	0.0005	0.0004
Parent_interface_delete	0.0010	0.0046	0.0045	0.0006	0.0012	0.0009
Additional_class	0.0010	0.0000	0.0014	0.0010	0.0018	0.0002
Removing_attribute_modifiability	0.0009	0.0013	0.0012	0.0007	0.0013	0.0012
Adding_attribute_modifiability	0.0008	0.0003	0.0005	0.0002	0.0003	0.0013
Removed_class	0.0006	0.0000	0.0026	0.0005	0.0006	0.0001
Adding_method_overridability	0.0005	0.0003	0.0002	0.0012	0.0002	0.0001
Removing_method_overridability	0.0005	0.0003	0.0002	0.0004	0.0003	0.0003
Return_type_insert	0.0004	0.0003	0.0002	0.0003	0.0004	0.0004
Return_type_delete	0.0004	0.0003	0.0000	0.0003	0.0001	0.0001
Removing_class_derivability	0.0003	0.0003	0.0005	0.0002	0.0002	0.0001
Parent_interface_change	0.0003	0.0005	0.0005	0.0002	0.0006	0.0006
Parent_class_insert	0.0003	0.0003	0.0002	0.0002	0.0002	0.0001
Parent_class_delete	0.0001	0.0000	0.0005	0.0001	0.0002	0.0001
Adding_class_derivability	0.0001	0.0000	0.0000	0.0001	0.0001	0.0000
Class_renaming	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 6: CTET Repair Actions Types and Probability χ_i for Different Heuristics to Build Versioning Transaction Bags.

Item	ALL	1-LC	1-SC	BFP	20-SC	20-LC
Statement_insert-Method_invocation	0.0694	0.0983	0.0897	0.0800	0.0881	0.0814
Statement_insert-If_statement	0.0662	0.0503	0.0000	0.0776	0.0806	0.0904
Statement_update-Method_invocation	0.0635	0.1311	0.1502	0.0549	0.0673	0.0622
Statement_delete-Method_invocation	0.0546	0.0557	0.0439	0.0586	0.0454	0.0423
Statement_delete-If_statement	0.0496	0.0232	0.0000	0.0505	0.0347	0.0429
Statement_insert-Variable_declaration_statement	0.0459	0.0083	0.0009	0.0509	0.0536	0.0536
Statement_insert-Assignment	0.0411	0.0338	0.0210	0.0456	0.0445	0.0456
Additional_functionality-Method	0.0411	0.0013	0.1381	0.0407	0.0669	0.0210
Statement_delete-Variable_declaration_statement	0.0372	0.0137	0.0104	0.0368	0.0283	0.0290
Statement_update-Variable_declaration_statement	0.0350	0.0908	0.0947	0.0283	0.0431	0.0411
Statement_delete-Assignment	0.0345	0.0132	0.0066	0.0303	0.0206	0.0232
Condition_expression_change-If_statement	0.0338	0.1223	0.1251	0.0277	0.0445	0.0529
Statement_update-Assignment	0.0291	0.0599	0.0671	0.0232	0.0282	0.0284

Additional_object_state-Attribute	0.0245	0.0072	0.0253	0.0245	0.0299	0.0156
Removed_functionality-Method	0.0219	0.0021	0.0451	0.0167	0.0222	0.0070
Statement_insert-Return_statement	0.0202	0.0325	0.0017	0.0189	0.0252	0.0281
Statement_parent_change-Method_invocation	0.0176	0.0204	0.0031	0.0219	0.0233	0.0309
Statement_delete-Return_statement	0.0175	0.0183	0.0000	0.0151	0.0139	0.0151
Alternative_part_insert-Else_statement	0.0169	0.0052	0.0000	0.0194	0.0171	0.0220
Alternative_part_delete-Else_statement	0.0144	0.0054	0.0000	0.0150	0.0095	0.0131
Removed_object_state-Attribute	0.0137	0.0077	0.0165	0.0114	0.0116	0.0071
Statement_update-Return_statement	0.0126	0.0353	0.0501	0.0084	0.0135	0.0123
Statement_ordering_change-Method_invocation	0.0119	0.0052	0.0092	0.0124	0.0099	0.0126
Statement_parent_change-If_statement	0.0104	0.0083	0.0021	0.0116	0.0142	0.0200
Statement_insert-Switch_case	0.0091	0.0031	0.0028	0.0104	0.0025	0.0038
Statement_parent_change-Variable_declaration_statement	0.0082	0.0015	0.0014	0.0089	0.0102	0.0129
Statement_parent_change-Assignment	0.0082	0.0121	0.0017	0.0100	0.0093	0.0123
Statement_parent_change-Return_statement	0.0077	0.0157	0.0005	0.0077	0.0092	0.0138
Statement_ordering_change-Variable_declaration_statement	0.0073	0.0015	0.0007	0.0079	0.0052	0.0075
Statement_insert-Catch_clause	0.0073	0.0036	0.0002	0.0088	0.0071	0.0091
Statement_ordering_change-Break_statement	0.0073	0.0015	0.0000	0.0131	0.0013	0.0073
Statement_delete-Switch_case	0.0073	0.0005	0.0002	0.0076	0.0007	0.0017
Parameter_insert-Single_variable_declaration	0.0072	0.0018	0.0007	0.0065	0.0053	0.0050
Statement_ordering_change-Switch_case	0.0070	0.0000	0.0007	0.0110	0.0005	0.0010
Statement_delete-Catch_clause	0.0066	0.0036	0.0000	0.0104	0.0043	0.0058
Statement_insert-Try_statement	0.0063	0.0000	0.0000	0.0064	0.0056	0.0070
Statement_insert-For_statement	0.0059	0.0010	0.0000	0.0061	0.0049	0.0054
Statement_ordering_change-Assignment	0.0059	0.0031	0.0014	0.0060	0.0043	0.0064
Decreasing_accessibility_change-Modifier	0.0057	0.0057	0.0071	0.0039	0.0048	0.0038
Statement_delete-Try_statement	0.0055	0.0000	0.0000	0.0079	0.0033	0.0042
Statement_delete-For_statement	0.0054	0.0010	0.0000	0.0053	0.0033	0.0040
Parameter_type_change-Simple_type	0.0052	0.0031	0.0038	0.0026	0.0028	0.0038
Parameter_delete-Single_variable_declaration	0.0051	0.0008	0.0000	0.0037	0.0026	0.0022
Statement_ordering_change-If_statement	0.0047	0.0028	0.0043	0.0051	0.0043	0.0066
Statement_insert-Throw_statement	0.0046	0.0008	0.0002	0.0037	0.0050	0.0049
Method_renaming-Method_declaration	0.0041	0.0021	0.0021	0.0027	0.0030	0.0023
Attribute_renaming-Field_declaration	0.0040	0.0008	0.0012	0.0026	0.0029	0.0022
Statement_insert-Break_statement	0.0040	0.0023	0.0012	0.0040	0.0019	0.0026
Increasing_accessibility_change-Modifier	0.0038	0.0124	0.0137	0.0031	0.0059	0.0086
Parameter_renaming-Single_variable_declaration	0.0036	0.0010	0.0009	0.0020	0.0023	0.0020
Statement_delete-Throw_statement	0.0032	0.0018	0.0005	0.0038	0.0023	0.0026
Return_type_change-Simple_type	0.0029	0.0013	0.0014	0.0013	0.0018	0.0016
Statement_delete-Break_statement	0.0027	0.0008	0.0000	0.0019	0.0006	0.0010
Statement_insert-While_statement	0.0027	0.0010	0.0000	0.0029	0.0026	0.0034
Attribute_type_change-Simple_type	0.0026	0.0021	0.0019	0.0013	0.0021	0.0019
Statement_delete-While_statement	0.0024	0.0005	0.0000	0.0024	0.0017	0.0023
Statement_update-Throw_statement	0.0023	0.0054	0.0061	0.0029	0.0027	0.0025
Statement_update-Super_constructor_invocation	0.0020	0.0072	0.0099	0.0013	0.0022	0.0021
Statement_ordering_change-Return_statement	0.0018	0.0034	0.0000	0.0020	0.0014	0.0024
Statement_parent_change-Break_statement	0.0016	0.0003	0.0002	0.0018	0.0005	0.0012
Statement_insert-Switch_statement	0.0015	0.0000	0.0000	0.0013	0.0004	0.0007
Parent_class_change-Simple_type	0.0015	0.0026	0.0024	0.0014	0.0016	0.0009
Statement_update-Switch_case	0.0014	0.0003	0.0002	0.0009	0.0007	0.0008
Parent_interface_insert-Simple_type	0.0013	0.0041	0.0045	0.0009	0.0017	0.0011
Parameter_ordering_change-Single_variable_declaration	0.0013	0.0000	0.0000	0.0009	0.0005	0.0004
Statement_insert-Continue_statement	0.0013	0.0036	0.0002	0.0013	0.0015	0.0022
Statement_delete-Switch_statement	0.0012	0.0000	0.0000	0.0008	0.0001	0.0004
Condition_expression_change-For_statement	0.0012	0.0013	0.0014	0.0010	0.0013	0.0012
Unclassified_change-Modifier	0.0011	0.0013	0.0019	0.0008	0.0010	0.0020
Statement_parent_change-For_statement	0.0011	0.0008	0.0000	0.0012	0.0017	0.0022
Parent_interface_delete-Simple_type	0.0010	0.0046	0.0045	0.0006	0.0012	0.0009
Additional_class-Class	0.0010	0.0000	0.0014	0.0010	0.0018	0.0002
Statement_parent_change-Continue_statement	0.0010	0.0028	0.0000	0.0010	0.0007	0.0017
Statement_delete-Continue_statement	0.0009	0.0008	0.0000	0.0006	0.0005	0.0007
Removing_attribute_modifiability-Modifier	0.0009	0.0013	0.0012	0.0007	0.0013	0.0012
Statement_delete-Super_constructor_invocation	0.0008	0.0023	0.0002	0.0007	0.0010	0.0006

Adding_attribute_modifiability-Modifier	0.0008	0.0003	0.0005	0.0002	0.0003	0.0013
Statement_insert-Super_constructor_invocation	0.0008	0.0023	0.0002	0.0006	0.0009	0.0006
Condition_expression_change-While_statement	0.0007	0.0018	0.0017	0.0004	0.0007	0.0009
Statement_insert-Synchronized_statement	0.0006	0.0000	0.0000	0.0009	0.0008	0.0008
Removed_class-Class	0.0006	0.0000	0.0026	0.0005	0.0006	0.0001
Statement_insert-Super_method_invocation	0.0005	0.0023	0.0019	0.0005	0.0008	0.0007
Adding_method_overridability-Modifier	0.0005	0.0003	0.0002	0.0012	0.0002	0.0001
Removing_method_overridability-Modifier	0.0005	0.0003	0.0002	0.0004	0.0003	0.0003
Statement_parent_change-Try_statement	0.0005	0.0000	0.0000	0.0006	0.0010	0.0011
Statement_parent_change-Throw_statement	0.0005	0.0003	0.0000	0.0005	0.0007	0.0009
Statement_update-Class_instance_creation	0.0005	0.0010	0.0014	0.0003	0.0002	0.0002
Return_type_change-Primitive_type	0.0005	0.0000	0.0000	0.0001	0.0002	0.0002
Statement_insert-Constructor_invocation	0.0004	0.0003	0.0000	0.0003	0.0006	0.0005
Statement_delete-Class_instance_creation	0.0004	0.0005	0.0007	0.0002	0.0003	0.0002
Statement_insert-Labeled_statement	0.0004	0.0000	0.0000	0.0003	0.0001	0.0003
Statement_parent_change-While_statement	0.0004	0.0003	0.0000	0.0005	0.0006	0.0007
Statement_ordering_change-Catch_clause	0.0004	0.0000	0.0000	0.0004	0.0005	0.0006
Statement_parent_change-Switch_case	0.0004	0.0000	0.0000	0.0002	0.0000	0.0001
Statement_ordering_change-For_statement	0.0004	0.0000	0.0000	0.0004	0.0004	0.0006
Parameter_type_change-Primitive_type	0.0004	0.0000	0.0002	0.0001	0.0002	0.0002
Statement_update-Switch_statement	0.0004	0.0000	0.0000	0.0001	0.0002	0.0002
Statement_update-Catch_clause	0.0004	0.0013	0.0017	0.0003	0.0007	0.0010
Parent_interface_change-Simple_type	0.0003	0.0005	0.0005	0.0002	0.0006	0.0006
Statement_delete-Labeled_statement	0.0003	0.0010	0.0000	0.0002	0.0002	0.0003
Statement_delete-Synchronized_statement	0.0003	0.0000	0.0000	0.0004	0.0004	0.0004
Parent_class_insert-Simple_type	0.0003	0.0003	0.0002	0.0002	0.0002	0.0001
Statement_insert-Class_instance_creation	0.0003	0.0010	0.0002	0.0002	0.0003	0.0003
Statement_delete-Super_method_invocation	0.0003	0.0023	0.0009	0.0002	0.0004	0.0004
Removing_class_derivability-Modifier	0.0003	0.0003	0.0005	0.0002	0.0002	0.0001
Attribute_type_change-Primitive_type	0.0003	0.0000	0.0000	0.0001	0.0002	0.0003
Return_type_insert-Simple_type	0.0002	0.0003	0.0002	0.0002	0.0002	0.0002
Statement_delete-Constructor_invocation	0.0002	0.0005	0.0000	0.0001	0.0002	0.0002
Return_type_delete-Simple_type	0.0002	0.0003	0.0000	0.0002	0.0001	0.0001
Return_type_insert-Primitive_type	0.0002	0.0000	0.0000	0.0001	0.0002	0.0002
Statement_ordering_change-Continue_statement	0.0002	0.0000	0.0000	0.0003	0.0001	0.0001
Statement_update-Super_method_invocation	0.0002	0.0005	0.0005	0.0002	0.0003	0.0002
Statement_ordering_change-Try_statement	0.0002	0.0000	0.0000	0.0002	0.0003	0.0002
Statement_update-Constructor_invocation	0.0002	0.0008	0.0007	0.0002	0.0003	0.0002
Condition_expression_change-Do_statement	0.0001	0.0000	0.0000	0.0000	0.0001	0.0001
Statement_ordering_change-Switch_statement	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
Unclassified_change-Variable_declaration_statement	0.0001	0.0000	0.0000	0.0002	0.0000	0.0000
Parent_class_delete-Simple_type	0.0001	0.0000	0.0005	0.0001	0.0002	0.0001
Return_type_delete-Primitive_type	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001
Statement_ordering_change-Throw_statement	0.0001	0.0000	0.0000	0.0001	0.0002	0.0002
Statement_update-Labeled_statement	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000
Unclassified_change-If_statement	0.0001	0.0000	0.0000	0.0003	0.0000	0.0000
Statement_ordering_change-Super_method_invocation	0.0001	0.0003	0.0007	0.0001	0.0002	0.0002
Unclassified_change-Assignment	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000
Statement_update-Break_statement	0.0001	0.0000	0.0000	0.0002	0.0000	0.0000
Statement_ordering_change-While_statement	0.0001	0.0000	0.0000	0.0002	0.0001	0.0001
Unclassified_change-Return_statement	0.0001	0.0000	0.0000	0.0002	0.0000	0.0000
Statement_delete-Do_statement	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001
Adding_class_derivability-Modifier	0.0001	0.0000	0.0000	0.0001	0.0001	0.0000
Statement_parent_change-Switch_statement	0.0001	0.0000	0.0000	0.0002	0.0001	0.0002
Statement_parent_change-Super_method_invocation	0.0001	0.0000	0.0000	0.0002	0.0002	0.0002
Statement_insert-Do_statement	0.0001	0.0000	0.0000	0.0002	0.0002	0.0002
Statement_update-Synchronized_statement	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001
Statement_delete-Assert_statement	0.0001	0.0000	0.0000	0.0000	0.0001	0.0001
Statement_insert-Enhanced_for_statement	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
Unclassified_change-Empty_statement	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Statement_update-Continue_statement	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Unclassified_change-For_statement	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Statement_ordering_change-Class_instance_creation	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Return_type_change-Parameterized_type	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Unclassified_change-Throw_statement	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Unclassified_change-Constructor_invocation	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Unclassified_change-Type_literal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Unclassified_change-Try_statement	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Statement_delete-Enhanced_for_statement	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Statement_parent_change-Do_statement	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
Unclassified_change-Switch_statement	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Parent_class_insert-Parameterized_type	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Statement_update-Assert_statement	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Statement_ordering_change-Labeled_statement	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Unclassified_change-Else_statement	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
Statement_parent_change-Class_instance_creation	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000
Class_renaming-Type_declaration	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Unclassified_change-Super_constructor_invocation	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Statement_ordering_change-Enhanced_for_statement	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Unclassified_change-Catch_clause	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Unclassified_change-While_statement	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Unclassified_change-Break_statement	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Statement_parent_change-Synchronized_statement	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
Statement_parent_change-Assert_statement	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Statement_insert-Assert_statement	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001
Unclassified_change-Switch_case	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Condition_expression_change-Enhanced_for_statement	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Unclassified_change-Line_comment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Statement_ordering_change-Synchronized_statement	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Parameter_type_change-Parameterized_type	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Parent_class_delete-Parameterized_type	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Statement_parent_change-Labeled_statement	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
Statement_ordering_change-Do_statement	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Unclassified_change-Method_invocation	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
Unclassified_change-Postfix_expression	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Unclassified_change-Block_comment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Return_type_insert-Parameterized_type	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

2.1 Repair Simulation Change Model CT

Repair Size	1	2	3	4	5	6	7	8	9
argouml	**5** (996)	**53** (638)	**315** (386)	**2682** (362)	**19975** (254)	∞(234)	∞(197)	∞(166)	∞(143)
carol	**5** (30)	**8** (15)	**595** (10)	**3906** (10)	**3130** (7)	∞(13)	∞(6)	∞(9)	∞(7)
columba	**6** (382)	**49** (255)	**417** (144)	**3522** (146)	**28118** (113)	**99766** (108)	∞(73)	∞(94)	∞(64)
dnsjava	**6** (165)	**48** (139)	**402** (71)	**1990** (82)	**34961** (54)	∞(50)	∞(33)	∞(44)	∞(17)
jEdit	**6** (115)	**46** (84)	**287** (53)	**3353** (48)	**27966** (32)	∞(30)	∞(29)	∞(32)	∞(26)
jboss	**6** (514)	**48** (353)	**393** (208)	**3248** (189)	**26872** (147)	∞(150)	∞(86)	∞(113)	∞(91)
jhotdraw6	**5** (21)	**37** (21)	**396** (9)	**517** (10)	**4769** (10)	**12428** (3)	**22242** (5)	∞(2)	∞(4)
junit	**5** (40)	**45** (39)	**268** (18)	**95763** (11)	**10305** (7)	∞(11)	∞(9)	∞(6)	∞(9)
log4j	**5** (223)	**45** (134)	**461** (68)	**2655** (70)	**13542** (64)	∞(42)	∞(41)	∞(48)	∞(37)
org.eclipse.jdt.core	**5** (1606)	**40** (1025)	**305** (657)	**2318** (631)	**12427** (392)	∞(416)	∞(314)	∞(309)	∞(262)
org.eclipse.ui.workbench	**5** (1184)	**53** (783)	**278** (414)	**2431** (464)	**15999** (326)	∞(305)	∞(215)	∞(192)	∞(185)
scarab	**6** (653)	**44** (346)	**340** (202)	**3138** (159)	**9668** (113)	**84180** (137)	∞(89)	∞(77)	∞(60)
struts	**5** (221)	**45** (133)	**284** (86)	**2686** (103)	**5862** (61)	**95470** (77)	∞(39)	∞(34)	∞(40)
tomcat	**6** (281)	**46** (167)	**399** (111)	**3323** (120)	**19468** (84)	∞(87)	∞(61)	∞(51)	∞(62)

Table 7: The median number of attempts(in bold) required to find the correct repair shape of fix transactions. The values in brackets indicate the number of fix transactions tested per project and per transaction size for repair model CT. The repair model CT is made from the distribution probability of changes included in 1-SC transaction bags.

Repair Size	1	2	3	4	5	6	7	8
argouml	**6** (996)	**13** (638)	**86** (386)	**267** (362)	**1394** (254)	**5977** (234)	**16748** (197)	**73430** (166)
carol	**7** (30)	**13** (15)	**121** (10)	**466** (10)	**494** (7)	**24117** (13)	**14019** (6)	**30631** (9)
columba	**3** (382)	**13** (255)	**68** (144)	**552** (146)	**940** (113)	**2111** (108)	**10908** (73)	**64606** (94)
dnsjava	**6** (165)	**13** (139)	**101** (71)	**218** (82)	**1553** (54)	**5063** (50)	**16363** (33)	∞(44)
jEdit	**3** (115)	**13** (84)	**58** (53)	**251** (48)	**2906** (32)	**3189** (30)	**5648** (29)	**23395** (32)
jboss	**6** (514)	**15** (353)	**88** (208)	**272** (189)	**1057** (147)	**6034** (150)	**13148** (86)	**38485** (113)
jhotdraw6	**7** (21)	**13** (21)	**159** (9)	**187** (10)	**1779** (10)	**611** (3)	∞(5)	**56391** (2)
junit	**3** (40)	**42** (39)	**596** (18)	∞(11)	**49345** (7)	∞(11)	**31634** (9)	∞(6)
log4j	**6** (223)	**15** (134)	**146** (68)	**665** (70)	**6459** (64)	**16879** (42)	**55582** (41)	∞(48)
org.eclipse.jdt.core	**6** (1606)	**26** (1025)	**93** (657)	**291** (631)	**1704** (392)	**4639** (416)	**18344** (314)	**74863** (309)
org.eclipse.ui.workbench	**3** (1184)	**13** (783)	**74** (414)	**311** (464)	**1023** (326)	**6035** (305)	**22864** (215)	**77532** (192)
scarab	**6** (653)	**16** (346)	**113** (202)	**420** (159)	**764** (113)	**3914** (137)	**13104** (89)	**59232** (77)
struts	**3** (221)	**17** (133)	**100** (86)	**222** (103)	**675** (61)	**4785** (77)	**16796** (39)	**95588** (34)
tomcat	**3** (281)	**13** (167)	**135** (111)	**431** (120)	**1068** (84)	**3497** (87)	**7407** (61)	**34240** (51)

Table 8: The median number of attempts(in bold) required to find the correct repair shape of fix transactions. The values in brackets indicate the number of fix transactions tested per project and per transaction size for repair model CT. The repair model CT is made from the distribution probability of changes included in 5-SC transaction bags.

Repair Size	1	2	3	4	5	6	7	8
argouml	**5** (996)	**20** (638)	**107** (386)	**482** (362)	**2160** (254)	**6439** (234)	**13733** (197)	**33239** (166)
carol	**9** (30)	**20** (15)	**104** (10)	**350** (10)	**642** (7)	**12378** (13)	**8994** (6)	**14219** (9)
columba	**4** (382)	**20** (255)	**105** (144)	**276** (146)	**1530** (113)	**1156** (108)	**5887** (73)	**36352** (94)
dnsjava	**5** (165)	**20** (139)	**114** (71)	**552** (82)	**755** (54)	**3651** (50)	**9206** (33)	∞(44)
jEdit	**4** (115)	**20** (84)	**81** (53)	**224** (48)	**1570** (32)	**1255** (30)	**2418** (29)	**10669** (32)
jboss	**5** (514)	**20** (353)	**104** (208)	**337** (189)	**1029** (147)	**6188** (150)	**8602** (86)	**25714** (113)
jhotdraw6	**9** (21)	**20** (21)	**228** (9)	**209** (10)	**3418** (10)	**279** (3)	**46060** (5)	**95767** (2)
junit	**4** (40)	**37** (39)	**494** (18)	**92607** (11)	∞(7)	∞(11)	**50868** (9)	∞(6)
log4j	**5** (223)	**20** (134)	**165** (68)	**611** (70)	**9125** (64)	**16351** (42)	**36244** (41)	∞(48)
org.eclipse.jdt.core	**5** (1606)	**20** (1025)	**105** (657)	**416** (631)	**1587** (392)	**4680** (416)	**11829** (314)	**35158** (309)
org.eclipse.ui.workbench	**4** (1184)	**19** (783)	**102** (414)	**327** (464)	**885** (326)	**4847** (305)	**9133** (215)	**37269** (192)
scarab	**5** (653)	**20** (346)	**127** (202)	**555** (159)	**791** (113)	**2942** (137)	**12977** (89)	**13423** (77)
struts	**4** (221)	**23** (133)	**106** (86)	**569** (103)	**1009** (61)	**8799** (77)	**7383** (39)	**36937** (34)
tomcat	**4** (281)	**19** (167)	**140** (111)	**416** (120)	**853** (84)	**1297** (87)	**3215** (61)	**15958** (51)

Table 9: The median number of attempts(in bold) required to find the correct repair shape of fix transactions. The values in brackets indicate the number of fix transactions tested per project and per transaction size for repair model CT. The repair model CT is made from the distribution probability of changes included in 10-SC transaction bags.

Repair Size	1	2	3	4	5	6	7	8
argouml	**5** (996)	**29** (638)	**164** (386)	**391** (362)	**2183** (254)	**5672** (234)	**13597** (197)	**29105** (166)
carol	**11** (30)	**27** (15)	**171** (10)	**639** (10)	**550** (7)	**10073** (13)	**9619** (6)	**8175** (9)
columba	**4** (382)	**27** (255)	**153** (144)	**267** (146)	**1261** (113)	**903** (108)	**4451** (73)	**28693** (94)
dnsjava	**4** (165)	**27** (139)	**169** (71)	**885** (82)	**720** (54)	**2453** (50)	**6610** (33)	**96561** (44)
jEdit	**4** (115)	**27** (84)	**129** (53)	**202** (48)	**1153** (32)	**1368** (30)	**2745** (29)	**7372** (32)
jboss	**4** (514)	**27** (353)	**165** (208)	**293** (189)	**855** (147)	**6132** (150)	**8689** (86)	**21508** (113)
jhotdraw6	**11** (21)	**27** (21)	**162** (9)	**244** (10)	**6693** (10)	**190** (3)	**83682** (5)	∞(2)
junit	**4** (40)	**33** (39)	**402** (18)	∞(11)	∞(7)	∞(11)	**26698** (9)	∞(6)
log4j	**5** (223)	**28** (134)	**178** (68)	**1127** (70)	**12551** (64)	**20263** (42)	**19718** (41)	∞(48)
org.eclipse.jdt.core	**4** (1606)	**27** (1025)	**165** (657)	**371** (631)	**1205** (392)	**4508** (416)	**9586** (314)	**21420** (309)
org.eclipse.ui.workbench	**4** (1184)	**27** (783)	**126** (414)	**303** (464)	**781** (326)	**3925** (305)	**6665** (215)	**24241** (192)
scarab	**4** (653)	**27** (346)	**167** (202)	**650** (159)	**729** (113)	**2698** (137)	**17857** (89)	**11350** (77)
struts	**5** (221)	**28** (133)	**173** (86)	**439** (103)	**1095** (61)	**6348** (77)	**6682** (39)	**30772** (34)
tomcat	**4** (281)	**26** (167)	**161** (111)	**410** (120)	**820** (84)	**1078** (87)	**2536** (61)	**15584** (51)

Table 10: The median number of attempts(in bold) required to find the correct repair shape of fix transactions. The values in brackets indicate the number of fix transactions tested per project and per transaction size for repair model CT. The repair model CT is made from the distribution probability of changes included in 20-SC transaction bags.

Repair Size	1	2	3	4	5	6	7	8
argouml	**6** (996)	**53** (638)	**147** (386)	**419** (362)	**2473** (254)	**6049** (234)	**12190** (197)	**16552** (166)
carol	**17** (30)	**47** (15)	**390** (10)	**1841** (10)	**1484** (7)	**3803** (13)	**2962** (6)	**8649** (9)
columba	**6** (382)	**22** (255)	**134** (144)	**254** (146)	**697** (113)	**1380** (108)	**5304** (73)	**21556** (94)
dnsjava	**6** (165)	**48** (139)	**392** (71)	**438** (82)	**818** (54)	**2781** (50)	**10734** (33)	∞(44)
jEdit	**6** (115)	**46** (84)	**89** (53)	**183** (48)	**1269** (32)	**1616** (30)	**2020** (29)	**9991** (32)
jboss	**6** (514)	**47** (353)	**253** (208)	**444** (189)	**1048** (147)	**8610** (150)	**5981** (86)	**28818** (113)
jhotdraw6	**17** (21)	**47** (21)	**140** (9)	**498** (10)	**26388** (10)	**229** (3)	∞(5)	∞(2)
junit	**6** (40)	**47** (39)	**1160** (18)	∞(11)	∞(7)	**70696** (11)	**24882** (9)	∞(6)
log4j	**6** (223)	**47** (134)	**389** (68)	**2409** (70)	**48093** (64)	**8748** (42)	**92785** (41)	**88560** (48)
org.eclipse.jdt.core	**6** (1606)	**43** (1025)	**211** (657)	**410** (631)	**1333** (392)	**5036** (416)	**10949** (314)	**22842** (309)
org.eclipse.ui.workbench	**6** (1184)	**30** (783)	**141** (414)	**289** (464)	**742** (326)	**4778** (305)	**6896** (215)	**15784** (192)
scarab	**6** (653)	**48** (346)	**163** (202)	**435** (159)	**718** (113)	**1998** (137)	**17669** (89)	**8722** (77)
struts	**6** (221)	**47** (133)	**388** (86)	**301** (103)	**1238** (61)	**8103** (77)	**8900** (39)	**36265** (34)
tomcat	**6** (281)	**18** (167)	**161** (111)	**399** (120)	**1008** (84)	**1035** (87)	**3494** (61)	**16588** (51)

Table 11: The median number of attempts(in bold) required to find the correct repair shape of fix transactions. The values in brackets indicate the number of fix transactions tested per project and per transaction size for repair model CT. The repair model CT is made from the distribution probability of changes included in BFP transaction bags.

Repair Size	1	2	3	4	5	6	7	8
argouml	**5** (996)	**37** (638)	**152** (386)	**417** (362)	**2436** (254)	**6661** (234)	**11243** (197)	**16388** (166)
carol	**17** (30)	**32** (15)	**213** (10)	**1296** (10)	**954** (7)	**3026** (13)	**2918** (6)	**21809** (9)
columba	**5** (382)	**25** (255)	**139** (144)	**334** (146)	**688** (113)	**1582** (108)	**7843** (73)	**20888** (94)
dnsjava	**5** (165)	**32** (139)	**213** (71)	**709** (82)	**1058** (54)	**3375** (50)	**13393** (33)	∞(44)
jEdit	**5** (115)	**30** (84)	**75** (53)	**154** (48)	**2046** (32)	**2633** (30)	**4247** (29)	**9381** (32)
jboss	**5** (514)	**31** (353)	**202** (208)	**506** (189)	**1054** (147)	**8775** (150)	**8844** (86)	**23145** (113)
jhotdraw6	**17** (21)	**32** (21)	**95** (9)	**517** (10)	**9956** (10)	**348** (3)	∞(5)	∞(2)
junit	**5** (40)	**42** (39)	**935** (18)	∞(11)	∞(7)	**50700** (11)	**56637** (9)	∞(6)
log4j	**5** (223)	**32** (134)	**233** (68)	**1463** (70)	**29316** (64)	**5718** (42)	**33218** (41)	**69107** (48)
org.eclipse.jdt.core	**5** (1606)	**31** (1025)	**204** (657)	**522** (631)	**1751** (392)	**6037** (416)	**16561** (314)	**30144** (309)
org.eclipse.ui.workbench	**5** (1184)	**31** (783)	**127** (414)	**380** (464)	**1086** (326)	**4542** (305)	**9407** (215)	**24271** (192)
scarab	**5** (653)	**31** (346)	**191** (202)	**652** (159)	**755** (113)	**1987** (137)	**17309** (89)	**14488** (77)
struts	**5** (221)	**31** (133)	**211** (86)	**422** (103)	**1818** (61)	**9147** (77)	**5759** (39)	**53695** (34)
tomcat	**5** (281)	**25** (167)	**190** (111)	**411** (120)	**1472** (84)	**1229** (87)	**4844** (61)	**22450** (51)

Table 12: The median number of attempts(in bold) required to find the correct repair shape of fix transactions. The values in brackets indicate the number of fix transactions tested per project and per transaction size for repair model CT. The repair model CT is made from the distribution probability of changes included in ALL transaction bags.

2.2 Repair Simulation Change Model CTET

Repair Size	1	2	3	4	5	6	7	8	9
argouml	**9** (996)	**370** (638)	**13704** (386)	∞(362)	∞(254)	∞(234)	∞(197)	∞(166)	∞(143)
carol	**8** (30)	**78** (15)	∞(10)	∞(10)	∞(7)	∞(13)	∞(6)	∞(9)	∞(7)
columba	**8** (382)	**182** (255)	**8115** (144)	∞(146)	∞(113)	∞(108)	∞(73)	∞(94)	∞(64)
dnsjava	**8** (165)	**1161** (139)	**38837** (71)	∞(82)	∞(54)	∞(50)	∞(33)	∞(44)	∞(17)
jEdit	**8** (115)	**153** (84)	**70402** (53)	∞(48)	∞(32)	∞(30)	∞(29)	∞(32)	∞(26)
jboss	**8** (514)	**1600** (353)	**14252** (208)	∞(189)	∞(147)	∞(150)	∞(86)	∞(113)	∞(91)
jhotdraw6	**7** (21)	**62** (21)	**958** (9)	∞(10)	∞(10)	∞(3)	∞(5)	∞(2)	∞(4)
junit	**8** (40)	**1759** (39)	∞(18)	∞(11)	∞(7)	∞(11)	∞(9)	∞(6)	∞(9)
log4j	**7** (223)	**101** (134)	**4279** (68)	∞(70)	∞(64)	∞(42)	∞(41)	∞(48)	∞(37)
org.eclipse.jdt.core	**8** (1606)	**2059** (1025)	**81214** (657)	∞(631)	∞(392)	∞(416)	∞(314)	∞(309)	∞(262)
org.eclipse.ui.workbench	**9** (1184)	**361** (783)	**14231** (414)	∞(464)	∞(326)	∞(305)	∞(215)	∞(192)	∞(185)
scarab	**8** (653)	**85** (346)	**4454** (202)	∞(159)	∞(113)	∞(137)	∞(89)	∞(77)	∞(60)
struts	**7** (221)	**358** (133)	**9358** (86)	∞(103)	∞(61)	∞(77)	∞(39)	∞(34)	∞(40)
tomcat	**7** (281)	**156** (167)	**14218** (111)	∞(120)	∞(84)	∞(87)	∞(61)	∞(51)	∞(62)

Table 13: The median number of attempts(in bold) required to find the correct repair shape of fix transactions. The values in brackets indicate the number of fix transactions tested per project and per transaction size for repair model CTET. The repair model CTET is made from the distribution probability of changes included in 1-SC transaction bags.

Repair Size	1	2	3	4	5	6	7	8	9
argouml	**10** (996)	**208** (638)	**3043** (386)	**33309** (362)	∞(254)	∞(234)	∞(197)	∞(166)	∞(143)
carol	**11** (30)	**145** (15)	**8717** (10)	∞(10)	**58205** (7)	∞(13)	∞(6)	∞(9)	∞(7)
columba	**11** (382)	**151** (255)	**1995** (144)	**51215** (146)	∞(113)	∞(108)	∞(73)	∞(94)	∞(64)
dnsjava	**11** (165)	**408** (139)	**4217** (71)	∞(82)	∞(54)	∞(50)	∞(33)	∞(44)	∞(17)
jEdit	**11** (115)	**144** (84)	**3090** (53)	**23302** (48)	∞(32)	∞(30)	∞(29)	∞(32)	∞(26)
jboss	**11** (514)	**290** (353)	**3267** (208)	**92063** (189)	∞(147)	∞(150)	∞(86)	∞(113)	∞(91)
jhotdraw6	**10** (21)	**118** (21)	**880** (9)	**22708** (10)	∞(10)	∞(3)	∞(5)	∞(2)	∞(4)
junit	**11** (40)	**1285** (39)	**4353** (18)	∞(11)	∞(7)	∞(11)	∞(9)	∞(6)	∞(9)
log4j	**7** (223)	**124** (134)	**1385** (68)	**29454** (70)	∞(64)	∞(42)	∞(41)	∞(48)	∞(37)
org.eclipse.jdt.core	**13** (1606)	**274** (1025)	**5154** (657)	**74267** (631)	∞(392)	∞(416)	∞(314)	∞(309)	∞(262)
org.eclipse.ui.workbench	**9** (1184)	**180** (783)	**1879** (414)	**32900** (464)	∞(326)	∞(305)	∞(215)	∞(192)	∞(185)
scarab	**10** (653)	**126** (346)	**1318** (202)	**22650** (159)	∞(113)	∞(137)	∞(89)	∞(77)	∞(60)
struts	**11** (221)	**218** (133)	**2887** (86)	**47203** (103)	∞(61)	∞(77)	∞(39)	∞(34)	∞(40)
tomcat	**10** (281)	**160** (167)	**2129** (111)	**23455** (120)	∞(84)	∞(87)	∞(61)	∞(51)	∞(62)

Table 14: The median number of attempts(in bold) required to find the correct repair shape of fix transactions. The values in brackets indicate the number of fix transactions tested per project and per transaction size for repair model CTET. The repair model CTET is made from the distribution probability of changes included in 5-SC transaction bags.

Repair Size	1	2	3	4	5	6	7	8	9
argouml	**13** (996)	**199** (638)	**3809** (386)	**34189** (362)	∞(254)	∞(234)	∞(197)	∞(166)	∞(143)
carol	**14** (30)	**217** (15)	**5863** (10)	∞(10)	**59433** (7)	∞(13)	∞(6)	∞(9)	∞(7)
columba	**14** (382)	**169** (255)	**2301** (144)	**40661** (146)	∞(113)	∞(108)	∞(73)	∞(94)	∞(64)
dnsjava	**14** (165)	**331** (139)	**4509** (71)	**76515** (82)	∞(54)	∞(50)	∞(33)	∞(44)	∞(17)
jEdit	**14** (115)	**175** (84)	**3754** (53)	**20256** (48)	∞(32)	∞(30)	∞(29)	∞(32)	∞(26)
jboss	**14** (514)	**270** (353)	**2782** (208)	**64260** (189)	∞(147)	∞(150)	∞(86)	∞(113)	∞(91)
jhotdraw6	**13** (21)	**115** (21)	**1350** (9)	**33871** (10)	∞(10)	∞(3)	∞(5)	∞(2)	∞(4)
junit	**14** (40)	**1060** (39)	**4472** (18)	∞(11)	∞(7)	∞(11)	∞(9)	∞(6)	∞(9)
log4j	**9** (223)	**152** (134)	**1611** (68)	**29279** (70)	∞(64)	∞(42)	∞(41)	∞(48)	∞(37)
org.eclipse.jdt.core	**17** (1606)	**296** (1025)	**4594** (657)	**58172** (631)	∞(392)	∞(416)	∞(314)	∞(309)	∞(262)
org.eclipse.ui.workbench	**12** (1184)	**185** (783)	**1989** (414)	**26960** (464)	∞(326)	∞(305)	∞(215)	∞(192)	∞(185)
scarab	**13** (653)	**139** (346)	**1581** (202)	**20599** (159)	∞(113)	∞(137)	∞(89)	∞(77)	∞(60)
struts	**14** (221)	**262** (133)	**4067** (86)	**45897** (103)	∞(61)	∞(77)	∞(39)	∞(34)	∞(40)
tomcat	**13** (281)	**178** (167)	**2499** (111)	**17274** (120)	∞(84)	∞(87)	∞(61)	∞(51)	∞(62)

Table 15: The median number of attempts(in bold) required to find the correct repair shape of fix transactions. The values in brackets indicate the number of fix transactions tested per project and per transaction size for repair model CTET. The repair model CTET is made from the distribution probability of changes included in 10-SC transaction bags.

Repair Size	1	2	3	4	5	6	7	8	9
argouml	**16** (996)	**262** (638)	**3869** (386)	**39846** (362)	∞(254)	∞(234)	∞(197)	∞(166)	∞(143)
carol	**16** (30)	**230** (15)	**9186** (10)	∞(10)	**70501** (7)	∞(13)	∞(6)	∞(9)	∞(7)
columba	**16** (382)	**184** (255)	**2759** (144)	**34348** (146)	∞(113)	∞(108)	∞(73)	∞(94)	∞(64)
dnsjava	**16** (165)	**359** (139)	**5383** (71)	**73244** (82)	∞(54)	∞(50)	∞(33)	∞(44)	∞(17)
jEdit	**16** (115)	**183** (84)	**3393** (53)	**24577** (48)	∞(32)	∞(30)	∞(29)	∞(32)	∞(26)
jboss	**15** (514)	**327** (353)	**3238** (208)	**62760** (189)	∞(147)	∞(150)	∞(86)	∞(113)	∞(91)
jhotdraw6	**16** (21)	**156** (21)	**2171** (9)	**50523** (10)	∞(10)	∞(3)	∞(5)	∞(2)	∞(4)
junit	**16** (40)	**1000** (39)	**5181** (18)	∞(11)	∞(7)	∞(11)	∞(9)	∞(6)	∞(9)
log4j	**11** (223)	**183** (134)	**2575** (68)	**39868** (70)	∞(64)	∞(42)	∞(41)	∞(48)	∞(37)
org.eclipse.jdt.core	**21** (1606)	**382** (1025)	**5057** (657)	**55975** (631)	∞(392)	∞(416)	∞(314)	∞(309)	∞(262)
org.eclipse.ui.workbench	**15** (1184)	**182** (783)	**2441** (414)	**30919** (464)	∞(326)	∞(305)	∞(215)	∞(192)	∞(185)
scarab	**15** (653)	**173** (346)	**2270** (202)	**33705** (159)	∞(113)	∞(137)	∞(89)	∞(77)	∞(60)
struts	**16** (221)	**339** (133)	**3364** (86)	**49330** (103)	∞(61)	∞(77)	∞(39)	∞(34)	∞(40)
tomcat	**15** (281)	**187** (167)	**2394** (111)	**22010** (120)	∞(84)	∞(87)	∞(61)	∞(51)	∞(62)

Table 16: The median number of attempts(in bold) required to find the correct repair shape of fix transactions. The values in brackets indicate the number of fix transactions tested per project and per transaction size for repair model CTET. The repair model CTET is made from the distribution probability of changes included in 20-SC transaction bags.

Repair Size	1	2	3	4	5	6	7	8	9
argouml	**19** (996)	**407** (638)	**6487** (386)	**99947** (362)	∞(254)	∞(234)	∞(197)	∞(166)	∞(143)
carol	**25** (30)	**417** (15)	**11467** (10)	∞(10)	∞(7)	∞(13)	∞(6)	∞(9)	∞(7)
columba	**17** (382)	**237** (255)	**4376** (144)	**51308** (146)	∞(113)	∞(108)	∞(73)	∞(94)	∞(64)
dnsjava	**25** (165)	**508** (139)	**7825** (71)	∞(82)	∞(54)	∞(50)	∞(33)	∞(44)	∞(17)
jEdit	**24** (115)	**265** (84)	**4044** (53)	**34097** (48)	∞(32)	∞(30)	∞(29)	∞(32)	∞(26)
jboss	**25** (514)	**422** (353)	**6031** (208)	∞(189)	∞(147)	∞(150)	∞(86)	∞(113)	∞(91)
jhotdraw6	**19** (21)	**423** (21)	**5741** (9)	**94185** (10)	∞(10)	∞(3)	∞(5)	∞(2)	∞(4)
junit	**25** (40)	**1213** (39)	**9622** (18)	∞(11)	∞(7)	∞(11)	∞(9)	∞(6)	∞(9)
log4j	**17** (223)	**352** (134)	**5801** (68)	**80747** (70)	∞(64)	∞(42)	∞(41)	∞(48)	∞(37)
org.eclipse.jdt.core	**31** (1606)	**414** (1025)	**7814** (657)	**86521** (631)	∞(392)	∞(416)	∞(314)	∞(309)	∞(262)
org.eclipse.ui.workbench	**24** (1184)	**278** (783)	**4583** (414)	**47871** (464)	∞(326)	∞(305)	∞(215)	∞(192)	∞(185)
scarab	**17** (653)	**274** (346)	**4646** (202)	**59593** (159)	∞(113)	∞(137)	∞(89)	∞(77)	∞(60)
struts	**24** (221)	**500** (133)	**8799** (86)	**86343** (103)	∞(61)	∞(77)	∞(39)	∞(34)	∞(40)
tomcat	**18** (281)	**340** (167)	**4113** (111)	**33663** (120)	∞(84)	∞(87)	∞(61)	∞(51)	∞(62)

Table 17: The median number of attempts(in bold) required to find the correct repair shape of fix transactions. The values in brackets indicate the number of fix transactions tested per project and per transaction size for repair model CTET. The repair model CTET is made from the distribution probability of changes included in BFP transaction bags.

Repair Size	1	2	3	4	5	6	7	8	9
argouml	**19** (996)	**364** (638)	**5749** (386)	**66875** (362)	∞(254)	∞(234)	∞(197)	∞(166)	∞(143)
carol	**21** (30)	**410** (15)	**14905** (10)	∞(10)	∞(7)	∞(13)	∞(6)	∞(9)	∞(7)
columba	**17** (382)	**257** (255)	**3770** (144)	**51588** (146)	∞(113)	∞(108)	∞(73)	∞(94)	∞(64)
dnsjava	**20** (165)	**508** (139)	**7936** (71)	∞(82)	∞(54)	∞(50)	∞(33)	∞(44)	∞(17)
jEdit	**19** (115)	**281** (84)	**4294** (53)	**40013** (48)	∞(32)	∞(30)	∞(29)	∞(32)	∞(26)
jboss	**20** (514)	**432** (353)	**5976** (208)	∞(189)	∞(147)	∞(150)	∞(86)	∞(113)	∞(91)
jhotdraw6	**19** (21)	**400** (21)	**4379** (9)	**75119** (10)	∞(10)	∞(3)	∞(5)	∞(2)	∞(4)
junit	**20** (40)	**985** (39)	**7228** (18)	∞(11)	∞(7)	∞(11)	∞(9)	∞(6)	∞(9)
log4j	**17** (223)	**291** (134)	**5843** (68)	**74260** (70)	∞(64)	∞(42)	∞(41)	∞(48)	∞(37)
org.eclipse.jdt.core	**25** (1606)	**375** (1025)	**8049** (657)	**96672** (631)	∞(392)	∞(416)	∞(314)	∞(309)	∞(262)
org.eclipse.ui.workbench	**20** (1184)	**288** (783)	**3985** (414)	**42118** (464)	∞(326)	∞(305)	∞(215)	∞(192)	∞(185)
scarab	**17** (653)	**277** (346)	**4347** (202)	**46263** (159)	∞(113)	∞(137)	∞(89)	∞(77)	∞(60)
struts	**20** (221)	**436** (133)	**6330** (86)	**83370** (103)	∞(61)	∞(77)	∞(39)	∞(34)	∞(40)
tomcat	**17** (281)	**301** (167)	**3466** (111)	**31254** (120)	∞(84)	∞(87)	∞(61)	∞(51)	∞(62)

Table 18: The median number of attempts(in bold) required to find the correct repair shape of fix transactions. The values in brackets indicate the number of fix transactions tested per project and per transaction size for repair model CTET. The repair model CTET is made from the distribution probability of changes included in ALL transaction bags.

3 Bug Fix Survey Summary

The survey data is available at supplementary file on the HAL entry of this document (see `http://hal.inria.fr`).

References

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