

Table 2. A comparison of the fault localization techniques. For each system, we show the technique with the best MFR in bold (the lower the better). *DepGraph w/o Code Change* shows the result after adopting *Dependency-Enhanced Coverage Graph*, and *DepGraph* shows the result of incorporating both *Dependency-Enhanced Coverage Graph* and Code Change Information. The number in the parentheses shows the percentage improvement over GNN (i.e., Grace) [28]. The best result is marked in bold.

System (# faults)	Techniques	Top-1	Top-3	Top-5	Top-10	MFR	MAR
Cli (39)	Ochiai	3	5	10	18	15.711	18.272
	Tarantula	3	3	8	15	15.763	18.051
	DeepFL	11	21	24	28	8.991	10.681
	GNN	14	24	26	30	7.861	9.903
	<i>DepGraph w/o Code Change</i>	15 (7%)	22 (-8%)	26 (0%)	31 (3%)	5.973 (24%)	7.118 (28%)
	<i>DepGraph</i>	<b>17 (21%)</b>	24 (0%)	<b>27 (4%)</b>	<b>34 (10%)</b>	<b>5.105 (30%)</b>	<b>6.223 (32%)</b>
Closure (174)	Ochiai	20	39	70	72	98.652	110.348
	Tarantula	20	37	68	70	97.745	109.634
	DeepFL	46	61	92	99	29.388	35.333
	GNN	51	78	102	121	12.854	14.814
	<i>DepGraph w/o Code Change</i>	58 (14%)	97 (24%)	123 (21%)	<b>148 (22%)</b>	4.844 (62%)	7.911 (47%)
	<i>DepGraph</i>	<b>60 (18%)</b>	<b>99 (27%)</b>	<b>126 (24%)</b>	<b>148 (22%)</b>	<b>4.542 (65%)</b>	<b>7.306 (51%)</b>
Codec (18)	Ochiai	3	12	17	17	2.701	3.461
	Tarantula	2	12	15	17	3.001	3.657
	DeepFL	5	10	12	16	2.742	4.803
	GNN	6	11	13	17	2.536	4.015
	<i>DepGraph w/o Code Change</i>	<b>7 (17%)</b>	<b>12 (9%)</b>	14 (8%)	16 (-6%)	<b>2.412 (5%)</b>	<b>3.265 (19%)</b>
	<i>DepGraph</i>	<b>7 (17%)</b>	10 (-9%)	14 (8%)	16 (-6%)	3.111 (-23%)	4.327 (-8%)
Collections (4)	Ochiai	1	1	2	2	3.871	3.431
	Tarantula	1	1	2	2	3.001	8
	DeepFL	1	1	2	2	1.512	1.519
	GNN	1	1	2	2	1.511	1.511
	<i>DepGraph w/o Code Change</i>	<b>1 (0%)</b>	1 (0%)	<b>2 (0%)</b>	2 (0%)	1.511 (0%)	1.511 (0%)
	<i>DepGraph</i>	<b>1 (0%)</b>	<b>2 (100%)</b>	<b>2 (0%)</b>	2 (0%)	<b>1.445 (4%)</b>	<b>1.445 (4%)</b>
Compress (47)	Ochiai	5	12	17	29	20.106	23.275
	Tarantula	6	13	17	29	16.979	19.927
	DeepFL	22	27	31	38	9.573	12.955
	GNN	23	29	34	42	5.383	6.987
	<i>DepGraph w/o Code Change</i>	24 (4%)	32 (10%)	<b>36 (6%)</b>	42 (0%)	4.384 (19%)	5.209 (25%)
	<i>DepGraph</i>	<b>25 (9%)</b>	<b>33 (14%)</b>	<b>36 (6%)</b>	<b>45 (7%)</b>	<b>3.361 (38%)</b>	<b>4.245 (39%)</b>
Csv (16)	Ochiai	3	8	10	12	5.625	5.782
	Tarantula	3	8	10	15	5.563	5.719
	DeepFL	7	8	9	11	5.623	5.971
	GNN	6	8	10	12	5.438	5.938
	<i>DepGraph w/o Code Change</i>	<b>8 (33%)</b>	<b>9 (13%)</b>	10 (0%)	<b>13 (8%)</b>	5.362 (1%)	5.581 (6%)
	<i>DepGraph</i>	<b>8 (33%)</b>	<b>9 (13%)</b>	<b>12 (20%)</b>	<b>13 (8%)</b>	<b>4.813 (12%)</b>	<b>5.001 (16%)</b>
Gson (18)	Ochiai	4	9	9	12	9.177	10.183
	Tarantula	4	9	10	13	9.056	9.667
	DeepFL	8	11	12	12	8.873	9.324
	GNN	11	13	14	15	6.471	6.755
	<i>DepGraph w/o Code Change</i>	12 (9%)	14 (8%)	15 (7%)	15 (0%)	2.177 (66%)	2.471 (63%)
	<i>DepGraph</i>	<b>14 (27%)</b>	<b>15 (15%)</b>	<b>16 (14%)</b>	<b>16 (7%)</b>	<b>1.553 (79%)</b>	<b>1.765 (74%)</b>
JacksonCore (26)	Ochiai	6	11	13	14	9.789	16.754
	Tarantula	6	12	14	16	4.368	16.892
	DeepFL	5	5	9	10	8.671	9.711
	GNN	9	13	14	15	6.471	6.755
	<i>DepGraph w/o Code Change</i>	9 (0%)	14 (8%)	<b>15 (13%)</b>	<b>17 (13%)</b>	3.474 (29%)	4.509 (28%)
	<i>DepGraph</i>	<b>12 (33%)</b>	<b>15 (15%)</b>	<b>15 (7%)</b>	16 (7%)	<b>3.052 (38%)</b>	<b>4.015 (36%)</b>
JacksonXml (6)	Ochiai	0	0	0	0	59.2	59.2
	Tarantula	1	1	1	3	27.8	27.8
	DeepFL	3	3	4	5	3.513	4.245
	GNN	3	3	4	5	2.401	2.401
	<i>DepGraph w/o Code Change</i>	<b>4 (33%)</b>	<b>5 (67%)</b>	5 (25%)	<b>5 (0%)</b>	0.411 (83%)	0.411 (83%)
	<i>DepGraph</i>	<b>4 (33%)</b>	<b>5 (67%)</b>	5 (25%)	<b>5 (0%)</b>	<b>0.409 (83%)</b>	<b>0.409 (83%)</b>
Jsoup (93)	Ochiai	15	40	48	57	14.944	20.209
	Tarantula	16	38	41	58	14.17	20.342
	DeepFL	33	39	46	49	10.23	11.444
	GNN	40	64	72	77	8.223	9.669
	<i>DepGraph w/o Code Change</i>	50 (25%)	70 (9%)	77 (7%)	82 (6%)	4.022 (51%)	6.815 (30%)
	<i>DepGraph</i>	<b>53 (33%)</b>	<b>73 (14%)</b>	<b>78 (8%)</b>	<b>83 (8%)</b>	<b>3.023 (63%)</b>	<b>4.6174 (52%)</b>
Lang (64)	Ochiai	25	45	51	59	4.68	5.15
	Tarantula	32	55	56	59	2.613	2.993
	DeepFL	42	53	55	57	2.833	3.08
	GNN	43	53	57	58	2.113	2.462
	<i>DepGraph w/o Code Change</i>	45 (5%)	<b>55 (4%)</b>	58 (2%)	<b>61 (5%)</b>	1.564 (26%)	1.902 (23%)
	<i>DepGraph</i>	<b>48 (12%)</b>	<b>55 (4%)</b>	<b>60 (5%)</b>	<b>61 (5%)</b>	<b>1.153 (45%)</b>	<b>1.481 (40%)</b>
Math (106)	Ochiai	23	52	62	82	9.73	11.72
	Tarantula	25	57	68	88	4.192	6.312
	DeepFL	52	81	90	95	3.95	4.911
	GNN	64	79	92	97	2.355	3.082
	<i>DepGraph w/o Code Change</i>	67 (5%)	90 (14%)	96 (4%)	100 (3%)	1.185 (50%)	1.528 (50%)
	<i>DepGraph</i>	<b>72 (13%)</b>	<b>92 (16%)</b>	<b>97 (5%)</b>	<b>102 (5%)</b>	<b>1.115 (53%)</b>	<b>1.454 (53%)</b>
Mockito (38)	Ochiai	7	14	18	23	20.22	24.77
	Tarantula	9	17	20	26	16.861	21.81
	DeepFL	10	18	23	26	13.541	17.001
	GNN	16	24	26	29	9.611	13.621
	<i>DepGraph w/o Code Change</i>	20 (25%)	28 (17%)	<b>34 (31%)</b>	<b>34 (17%)</b>	2.361 (75%)	3.307 (76%)
	<i>DepGraph</i>	<b>21 (31%)</b>	<b>29 (21%)</b>	32 (23%)	<b>34 (17%)</b>	<b>2.194 (77%)</b>	<b>2.998 (78%)</b>
Time (26)	Ochiai	6	12	13	16	16.14	18.98
	Tarantula	7	12	14	16	15.354	17.121
	DeepFL	12	15	18	20	12.722	13.754
	GNN	11	16	20	21	7.842	8.448
	<i>DepGraph w/o Code Change</i>	16 (45%)	19 (19%)	20 (0%)	<b>22 (5%)</b>	3.321 (58%)	4.465 (47%)
	<i>DepGraph</i>	<b>17 (55%)</b>	<b>20 (25%)</b>	<b>21 (5%)</b>	<b>22 (5%)</b>	<b>3.044 (61%)</b>	<b>4.371 (48%)</b>
Total (675)	Ochiai	121	260	340	413	20.753	24.038
	Tarantula	135	278	350	427	16.95	20.567
	DeepFL	257	353	427	468	8.726	10.331
	GNN	298	416	486	541	5.678	6.858
	<i>DepGraph w/o Code Change</i>	336 (13%)	470 (13%)	534 (10%)	588 (9%)	3.049 (46%)	3.957 (42%)
	<i>DepGraph</i>	<b>359 (20%)</b>	<b>481 (16%)</b>	<b>541 (11%)</b>	<b>597 (10%)</b>	<b>2.562 (55%)</b>	<b>3.272 (52%)</b>