

EM Analysis @ICSE2014

[Overview](#)[EM Categories](#)[EM Benchmarks](#)[Paper](#)[Contact](#)

Study of Equivalent and Stubborn Mutation Operators Using Human Analysis of Equivalence

Overview

Though mutation testing has been widely studied for more than thirty years, the prevalence and properties of equivalent mutants remain largely unknown. We report on the causes and prevalence of equivalent mutants and their relationship to stubborn mutants (those that remain undetected by a high quality test suite, yet are non-equivalent). Our results, based on manual analysis of 1,194 mutants from 18 programs, reveal a highly uneven distribution of equivalence and stubbornness. For example, the ABS class and half UOI class generate many equivalent and almost no stubborn mutants, while the LCR class generates many stubborn and few equivalent mutants. We conclude that previous test effectiveness studies based on fault seeding could be skewed, while developers of mutation testing tools should prioritise those operators that we found generate disproportionately many stubborn (and few equivalent) mutants.

Equivalent Mutants Categories

A Summary of the Human-Evaluated Decision Procedure for Mutant Equivalence

Case 1: Mutant cannot be reached by any test input

- Case 1.1 (normal): Mutated statement or predicate cannot be reached
- Case 1.2 (short-circuit): Mutated sub-expression never evaluated though its containing predicate is

Case 2: Mutant is reached by at least one test input, but no test causes state infection

- Case 2.1 (context free): Infection can never occur in any state
- Case 2.2 (context sensitive): Not context free, but infection cannot occur in any reaching state
- Case 2.3 (subpath equivalence): Mutation changes path executed, but all paths are equivalent

Case 3: Mutant is reached and infects the state, but no infection propagates to an output

- Case 3.1 (unobservable): No output statement mentions an infected variable
- Case 3.2 (observable): Outputs mention infected variable(s), but infection fails to reach any

Equivalent Mutants Benchmark

Subjects	C1.1	C1.2	C2.1	C2.2	C2.3	C3.1	C3.2
Min	0	0	0	<u>1</u>	0	<u>8</u>	0
Bubble Sort	0	0	0	0	0	<u>3</u>	<u>6</u>
Profit	0	0	0	<u>17</u>	<u>5</u>	<u>24</u>	0
Mid	0	0	0	0	<u>5</u>	<u>14</u>	0
Prime_num	0	0	0	<u>5</u>	0	<u>4</u>	0
Triangle	0	0	0	<u>13</u>	0	<u>15</u>	<u>12</u>
Insert	0	0	0	<u>2</u>	0	<u>9</u>	<u>8</u>
Day	0	0	0	<u>6</u>	0	<u>8</u>	0
Calendar	0	0	0	<u>25</u>	0	<u>16</u>	0
Carsimulator	0	0	0	<u>13</u>	<u>7</u>	<u>24</u>	0
Tcas	0	<u>44</u>	0	<u>26</u>	0	<u>20</u>	0

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Subjects	C1.1	C1.2	C2.1	C2.2	C2.3	C3.1	C3.2
Defroster	0	<u>54</u>	0	<u>41</u>	0	<u>48</u>	0
Schedule	0	0	0	<u>28</u>	0	<u>20</u>	0
Hashmap	0	0	0	<u>47</u>	0	<u>20</u>	0
Replace	0	0	0	<u>135</u>	0	<u>80</u>	0
Space	0	0	0	<u>72</u>	<u>1</u>	<u>14</u>	0
Flex	0	0	0	<u>40</u>	0	0	0
Make	0	0	0	<u>32</u>	0	<u>28</u>	0

Stubborn mutants

All stubborn mutants: [download](#)

Paper

A preprint version of the paper can be download from [here](#).

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