Metamorphic Testing - IV

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Effectiveness of Metamorphic Testing

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Metamorphic Group of Inputs

For a given MR, source test case(s) and the corresponding follow-up test case(s) form a metamorphic group of inputs, or simply metamorphic group (MG)

Note:

An MR may have many metamorphic groups

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Example

For the MR

- if y= x+360, then *sin*(x)= *sin*(y)

- 29.8 is the source test case
- 389.8 (=29.8+360) is the follow-up test case
- this pair of (29.8, 389.8) is referred to as a metamorphic group of inputs for this MR

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Metamorphic Testing (A Simplified Form)

- Define and execute source (initial) test cases using some test case selection strategies
- Identify some properties of the problem (referred to as the metamorphic relations)
- Construct and execute follow-up test cases from the source test cases with reference to the identified metamorphic relations
- Verify the metamorphic relations using the computed outputs

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Example

- An existing test case of 29.8; execute the program with this test case as input
- A property – metamorphic relation (MR)
  - if y= x+360, then *sin*(x)= *sin*(y)
- For x= 29.8, compute y=29.8+360 = 389.8
- (29.8, 389.8) forms a MG for this MR
- Execute the program with 389.8 as input
- Check whether *sin*(29.8) = *sin*(389.8)

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Example (continued)

Check whether *sin*(29.8) = *sin*(389.8)

Two possible outcome

- True – satisfaction of MR with respect to the metamorphic group of (29.8, 389.8)
- False – violation of MR with respect to the metamorphic group of (29.8, 389.8)

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The outcome of applying metamorphic testing is either

- Satisfaction of MR with respect to a metamorphic group: not guaranteeing the correctness of the program; or
- Violation of MR with respect to a metamorphic group: guaranteeing that the program is faulty

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Since an MR may have many metamorphic groups (MGs), it may be satisfied with some MGs but may be violated with some other MGs, for example

- satisfied by (29.8, 389.8)
- satisfied by (10.5, 370,5)
- violated by (100.0, 460.0)
- satisfied by (50.0, 410.0)
- ……

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Effectiveness of MR

For a specific MR, suppose

- there are N MGs, namely, mg-1, mg-2, ……., mg-N;
- MR is satisfied by S MGs; and
- MR is violated by V MGs

The violation rate of this MR with respect to this set of MGs is defined as (V/N)

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Effectiveness of MR (continued)

Note

- $N = S + V$
- A higher violation rate implies a higher failure detection effectiveness for this MR
- Violation rates depend on the sets of MGs
- Since follow-up test cases are constructed from the source test cases, therefore violation rates depend on the test case selection strategies for source test cases

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Effectiveness of MT

For a specific program P, suppose

- there are M MRs, namely, MR-1, MR-2, ……., MR-M;
- For each MR-I, it is satisfied by $S\text{-}I$ MGs and violated by $V\text{-}I$ MGs

Define

$V = V\text{-}1 + V\text{-}2 + \ldots\ldots + V\text{-}M$

$S = S\text{-}1 + S\text{-}2 + \ldots\ldots\ldots + S\text{-}M$

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Effectiveness of MT (continued)

For program P, the violation rate is defined as $(V/(V+S))$.

Note:

- the violation rate depends on what MRs are used
- the violation rate depends on what MGs are used for each MR
- the violation rate depends on what test case selection strategies for source test cases are used for each MR

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Example

Consider the sine program

- MR-1 is

  if y= x+360, then *sin*(x)= *sin*(y)
- MR-2 is

  if y= -x, then *sin*(x)= -*sin*(y)

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Example (continued)

For MR-1

if y= x+360, then *sin*(x)= *sin*(y)

- satisfied by (29.8, 389.8)
- satisfied by (10.5, 370,5)
- violated by (100.0, 460.0)
- satisfied by (50.0, 410.0)
- …….

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Example (continued)

For MR-2

if y= -x, then *sin*(x)= -*sin*(y)

- violated by (29.8, -29.8)
- satisfied by (-40.5, 40,5)
- satisfied by (-100.0, 100.0)
- violated by (123.4, -123.4)
- …….

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Example (continued)

Note

- (29.8, 389.8) satisfying MR-1: if y= x+360, then *sin*(x)= *sin*(y)
- (29.8, -29.8) violating MR-2: if y= -x, then *sin*(x)= -*sin*(y)

V = *V-1* + *V-2* = 1 + 2 = 3

S = *S-1* + *S-2* = 3 + 2 = 5

Violation Rate = 3/ (3 + 5) = 3/8

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Effectiveness of MT

- the violation rate depends on what MRs are used
- the violation rate depends on what test case selection strategies for source test cases are used for each MR

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Summary

Reference

T. Y. Chen, F.-C. Kuo, H. Liu, P. L. Poon, D. Towey, T. H. Tse and Z. Q. Zhou, Metamorphic Testing: A Review of Challenges and Opportunities, *ACM Computing Surveys*, Vol. 51(1), 4:1-4:27, 2018.