

Effectiveness of Metamorphic Testing

### 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

### 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)

## 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

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)

### 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-I* MGs and violated by *V-I* MGs

#### Define

$$V = V-1 + V-2 + \dots + V-M$$
  
 $S = S-1 + S-2 + \dots + S-M$ 

# 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  $sin(x) = -sin(y)$ 

# 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)
- ...........

## Example (continued)

#### Note

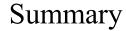
- (29.8, 389.8) satisfying MR-1: if y=x+360, then sin(x)=sin(y)
- (29.8, -29.8) violating MR-2: if y= -x, then sin(x) = -sin(y)

$$V = V-1 + V-2 = 1 + 2 = 3$$
  
 $S = S-1 + S-2 = 3 + 2 = 5$   
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



# 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.