Lecture

Mutation Testing - III

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Mutation Testing

- To measure the effectiveness
- To measure the adequacy
- To generate test cases

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Outline

- Equivalent mutants
- In the absence of test oracle
- Effectiveness measurements for MRs
- Prioritizations of MRs

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Equivalent Mutants

A mutant (M) of a reference program (P) is said to be an equivalent mutant, if for any input, the outputs of M and P are identical

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Example: Equivalent Mutants

Given program	Equivalent Mutant
…………	………
C=A+B	C=B+A
.....……..	…..………
………….	…………

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Example: Equivalent Mutants

Given program	Equivalent Mutant
…………	………
B=K	B=K
C=A+B	C=A+K
.....……..	…..………
………….	…………

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Example: Equivalent Mutants

Given program	Equivalent Mutant
…………	………
If (A != B)	If (A != B)
Then (If (A>B)	Then (If (A>=B)
Then C=A+B	Then C=A+B
.....……..	….……….
………….	…………

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Impact of Equivalent Mutants

- Test adequacy
- Mutation scores

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Test Adequacy

- Use a set of mutants as a test adequacy criterion
  - killing all mutants

Exclude equivalent mutants

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Example

Suppose

- SM={M1, M2, M3, M4, M5, M6}
- Set of killed mutants = {M1, M2, M3, M5}

Then, MS = (4 / 6) = 2/3 (or 0.67)

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Example (continued)

Suppose

- SM={M1, M2, M3, M4, M5, M6}
- Set of killed mutants = {M1, M2, M3, M5}

What happens if M4 and M6 are equivalent mutants?

Is MS = 0.67 still a good measurement?

Example (continued)

Suppose

- SM={M1, M2, M3, M4, M5, M6}
- Set of killed mutants = {M1, M2, M3, M5}

What happens if M4 and M6 are equivalent mutants?

Intuitively, perfect testing!

Mutation Score

Needs to redefine mutation score

The mutation score (MS) for TC and SM is defined as the ratio of the number of killed mutants and the total number of non-equivalent mutants.

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Equivalent Mutants

Unfortunately, identification of equivalent mutants is extremely difficult

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Without Test Oracle

How to use mutation testing, in the absence of test oracle for P?

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Without Test Oracle (continued)

Given an MR which involves only one source input (SI) and one follow-up input (FI)

Define a pair of (SI, FI) as a metamorphic test group (MTG)

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Without Test Oracle (continued)

Example: sine program

MR1: if y=x+360, then sin(y)=sin(x)

(26, 386), (95, 455), (-20, 340) are MTGs for MR1

MR2: if y=-x, then sin(y)= - sin(x)

(26, -26), (95, -95), (-20, 20) are MTGs for MR2

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Without Test Oracle (continued)

For sum program,

MR3: if FI is the reverse of SI,
then sum(FI)=sum(SI)

([3, 9, 6, 2, 11, 8, 15], [15, 8, 11, 2, 6, 9, 3]),
([5, 5, 8, 5, 5], [5, 5, 8, 5, 5]) are MTGs for MR3

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Without Test Oracle (continued)

Two important correspondence between

- Test cases and MTGs
- The output relationship of P and M and the validation outcome of MRs
  - killing a mutant corresponding to violation of MR

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Without Test Oracle (continued)

Consider sin function with

- Set of Mutants = {M1, M2, M3, M4}
- MR1: if y=x+360, then sin(y)=sin(x)
  - (26, 386), (95, 455), (-20, 340) are MTGs

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Without Test Oracle (continued)

For MTG (26, 386), suppose

- M1(26) =/= M1(386), MR is violated with M1
- M2(26)=M2(386), MR is satisfied with M2
- M3(26)=M3(386), MR is satisfied with M3
- M4(26) =/= M4(386), MR is violated with M4

MTG (26, 386) kills M1 and M4

Without Test Oracle (continued)

For MTG (95, 455), suppose

- M1(95) =/= M1(455), MR is violated with M1
- M2(95) =/= M2(455), MR is violated with M2
- M3(95) =/= M3(455), MR is violated with M3
- M4(95) = M4(455), MR is satisfied with M4

MTG (95, 455) kills M1, M2 and M3

Without Test Oracle (continued)

For MTG (-20, 340), suppose
- M1(-20) =/= M1(340), MR is violated with M1
- M2(-20) = M2(340), MR is satisfied with M2
- M3(-20) =/= M3(340), MR is violated with M3
- M4(-20) =/= M4(340), MR is violated with M4

MTG (-20, 340) kills M1, M3 and M4

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Violation Results

	M1	M2	M3	M4
(26, 386)	v	s	s	v
(95, 455)	v	v	v	s
(-20, 340)	v	s	v	v

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Violation Results

	M1	M2	M3	M4
(26, 386)	s	s	s	v
(95, 455)	v	v	v	s
(-20, 340)	v	s	v	v

- Number of violations = 7
- Number of satisfactions = 5
- Effectiveness for MR1 = 7/ (7+5) = 0.58

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Effectiveness -Violation Ratio

This effectiveness ratio depends

- The set of MTGs
- The set of mutants

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Effectiveness of MRs

For an MR,

- Identify a set of MTG for this MR (SMTG)
- Identify a set of mutants (SM)

Effectiveness of an MR:

ratio of violations = number of violations / (total number of violations and satisfactions)

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Effectiveness -Violation Ratio

This effectiveness ratio depends

- The set of MTGs
- The set of mutants

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Effectiveness -Violation Ratio

This effectiveness ratio depends

- The set of MTGs
  - Various test case selection methods to generate source test cases
- The set of mutants
  - Mimic real life faults

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Prioritization of MRs

- Given a group of MRs
  - MR1, MR2, MR3, …..
- Design a set of mutants
- Design a set of source inputs
  - some adaptions may be required in this step
- Compute the expected ratios of violations for these MRs to prioritize them

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Mutants

- A slightly mutated version of a given program through the application of mutation operators
- Successfully compiled
- Programming language dependent
- Mimic real life faults (bugs)

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Summary

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References

- Y. Jia and M. Harman, “An Analysis and Survey of the Development of Mutation Testing”, IEEE Transactions on Software Engineering, Vol. 37(5), 649-678, 2011.

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