Metamorphic Testing Part 1

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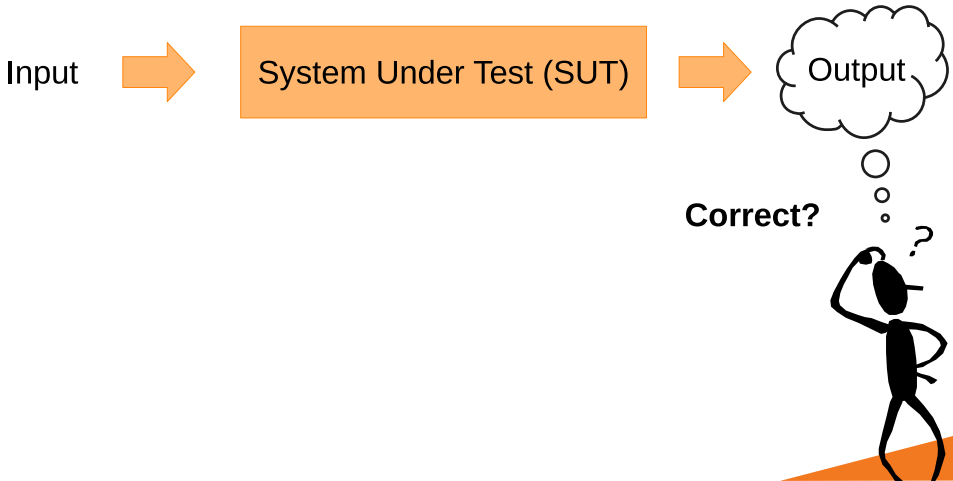
Introduction

Test Oracle

Mechanism to decide whether a test output is correct or not



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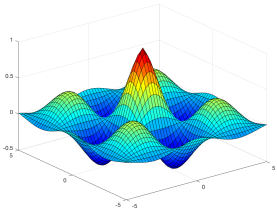
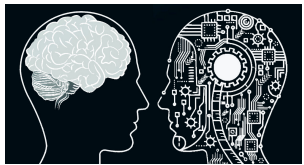
Introduction

Oracle Problem

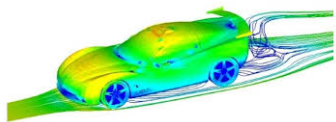
Sometimes it is not feasible to check the correctness of a test output



Scientific Calculations



Artificial Intelligence



Simulation & Modeling

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Let’s see some examples

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Examples

G

Source = s
Destination = d

shortestPath(G, s, d)

{e,g,h,t,x,z}

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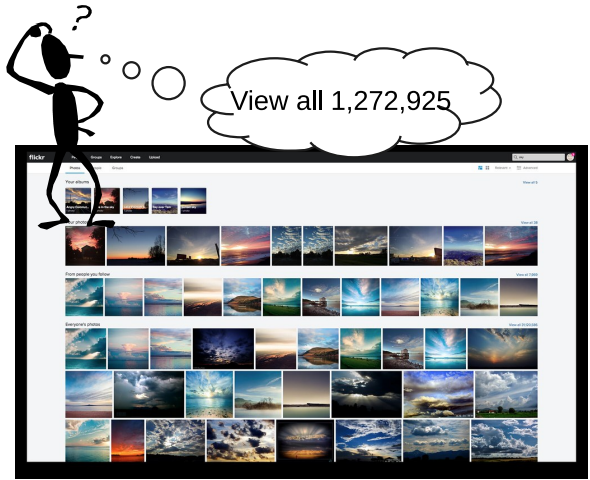
Examples

flickr

Software



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Examples

Source test case

Graph G
Source s
Destination d

shortestPath(G, s, d)

{e, g, h, t, x, z}

|shortestPath(G, s, d)|
=
|shortestPath(G, d, s)|

Follow-up test case

Graph G
Source s
Destination d

shortestPath(G, d, s)

{z, x, g, e}

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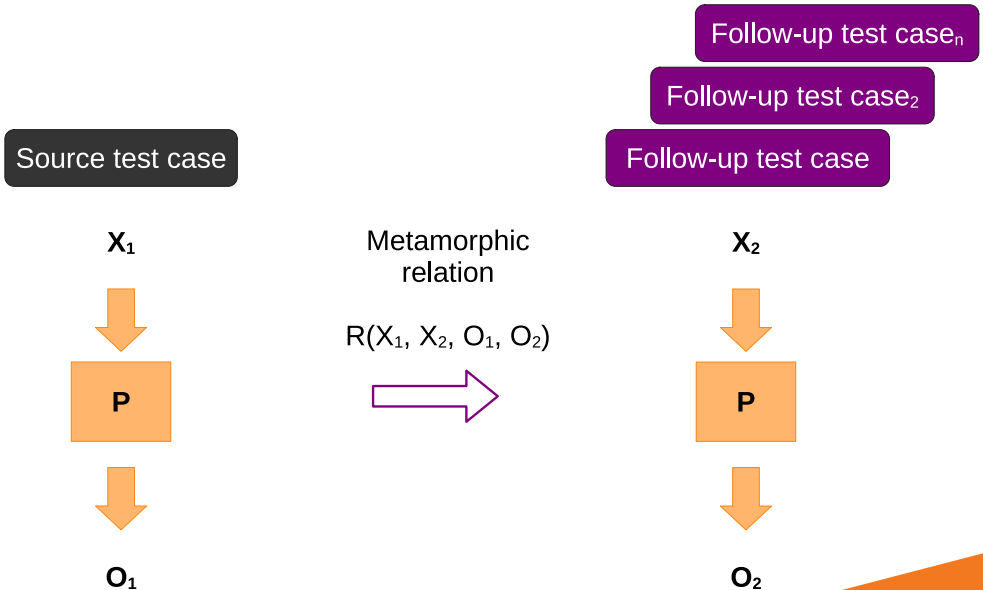
Examples



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Metamorphic Testing Process

1. Identification of metamorphic relations.
2. Generation/Selection of source test cases.
3. Generation of follow-up test cases.
4. Checking of metamorphic relations

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Oh, I get it. This is about alleviating the oracle problem. Is that it?

Yes! but MT can also support test data generation!

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Test Data Generation

|shortestPath(G, s, d)|
=
|shortestPath(G, d, s)|

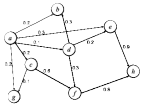
Metamorphic relation

Graph database

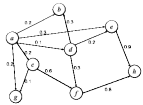
MT 1

|shortestPath(G, k, t)|
=
|shortestPath(G, t, k)|

MT 2



|shortestPath(P, c, a)|
=
|shortestPath(P, c, a)|



MT 3

|shortestPath(S, 2, 41)|
=
|shortestPath(S, 41, 2)|

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Test Data Generation

If Q_2 == Q_1 AND size = large
then Count(Q_2) <= Count (Q_1)

Metamorphic relation

+

Random word generator

→

MT 1

Q_1 = “dog”
Q_2 = “dog”, size = large
Count(Q_2) <= Count(Q_1)

MT 2

Q_1 = “wind”
Q_2 = “wind”, size = large
Count(Q_2) <= Count(Q_1)

MT 3

Q_1 = “thing”
Q_2 = “thing”, size = large
Count(Q_2) <= Count(Q_1)

MT 4

Q_1 = “money”
Q_2 = “money”, size = large
Count(Q_2) <= Count(Q_1)

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State of the art

Domains

From a survey of 84 Case Studies

- Numerical programs ~5%
- Variability and decision support ~5%
- Compilers ~4%
- Components ~3%
- Autonomous Vehicles ~2%
- Bioinformatics ~8%
- Machine Learning ~8%
- Simulation and Modeling ~8%
- Embedded Systems ~8%
- Computer Graphics ~11%
- Web Services/Apps ~14%
- Other (Adobe, NASA, CyberSec) ~24%

Lessons Learned

Lesson Learned

Metamorphic testing requires good knowledge of the problem domain

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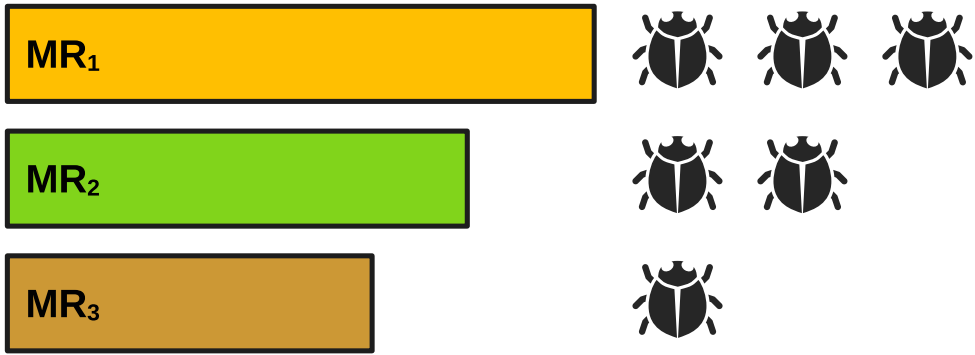
Lessons Learned

Lesson Learned

Different metamorphic relations can have different fault-detection capability



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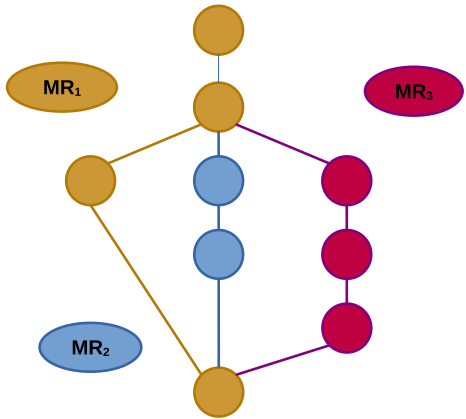
Lessons Learned

Lesson Learned

Metamorphic relations should be diverse so they exercise different parts of the program.



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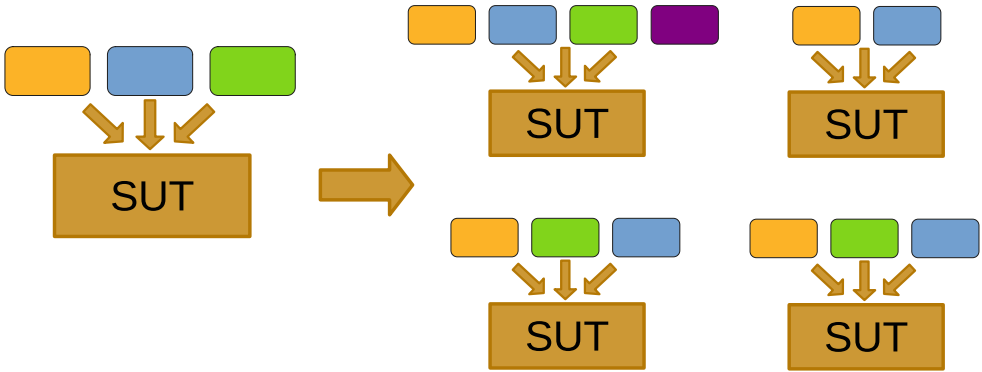
Lessons Learned

Lesson Learned

Two common approaches for the construction of metamorphic relations: **input-driven** vs. output-driven



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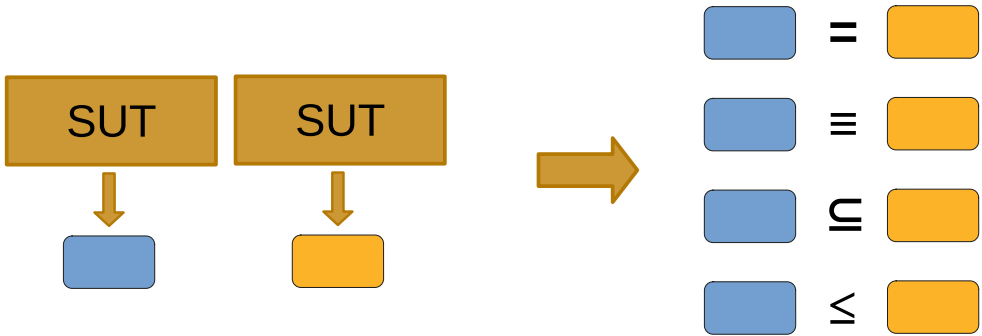
Lessons Learned

Lesson Learned

Two common approaches for the construction of metamorphic relations: input-driven vs. **output-driven**



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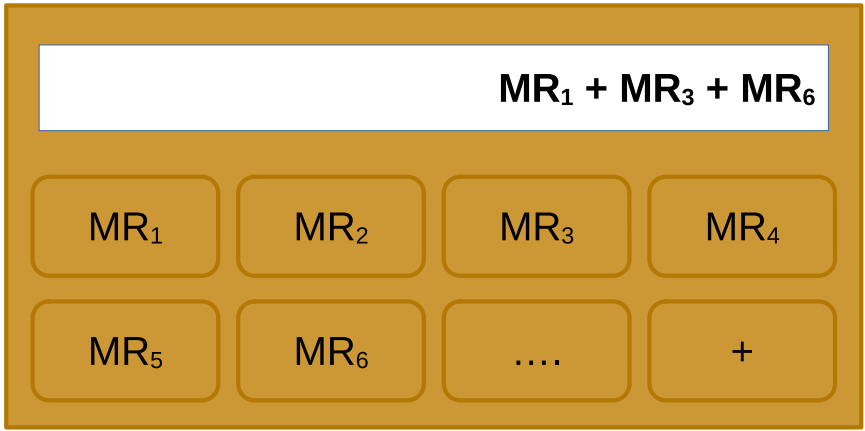
Lessons Learned

Lesson Learned

Metamorphic relations can be combined



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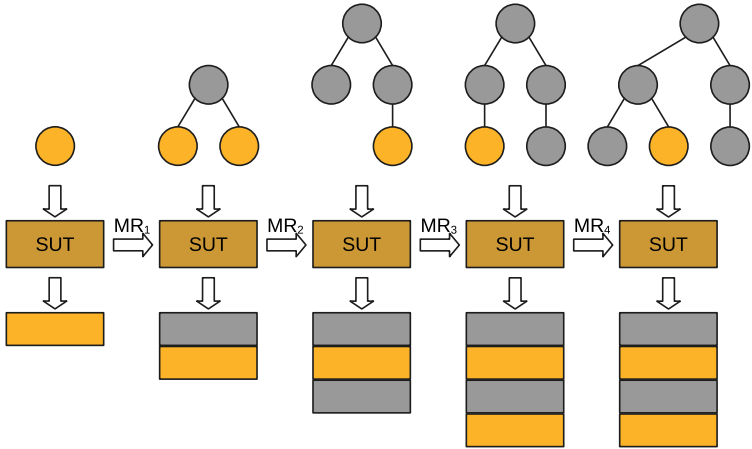
Lessons Learned

Lesson Learned

Metamorphic relations can be combined



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Lessons Learned

Lesson Learned

The automated discovery of metamorphic relations seems feasible in certain domains

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Challenges

- Systematic guidelines for the construction of good metamorphic relations
- Generation of likely metamorphic relations
- Non-functional metamorphic testing
- Provide tools to foster the use of the technique

Are there any questions?

Lecture borrowed from Segura and Zhou's presentation on "Metamorphic Testing 20 Years Later: A Hands-on Introduction" as presented at the 40th International Conference on Software Engineering.