METAMORPHIC AND DIFFERENTIAL TESTING

Myra Cohen, BSSw Fellow

https://www.cs.iastate.edu/~mcohen

mcohen@iastate.edu

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Laboratory for Variability-Aware Assurance and
Testing of Organic Programs   LaVA-OPs
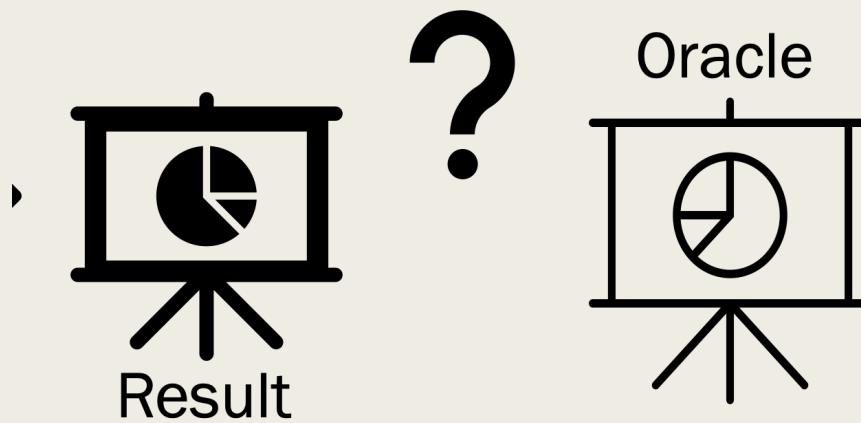
Overview

Motivation

Differential Testing

Metamorphic Testing

What is the Correct Answer?

Result ? Oracle

Trivial Oracles

Program crashes

Core dump

Segmentation error

Overflow

Program hangs

Trivial Oracles

- Good when we don't have a known result

- Weakest oracle since it only shows that the program fails/not that the result is incorrect

- Exact oracles are easy to compute in some programs

```
def classify_triangle(a, b, c):
    # Sort the sides so that a <= b <= c
    if a > b:
        tmp = a
        a = tmp    #fault should be a=b
        b = tmp

    if a > c:
        tmp = a
        a = c
        c = tmp

    if b > c:
        tmp = b
        b = c
        c = tmp

    if a + b <= c:
        return TriangleType.INVALID
    elif a == b and b == c:
        return TriangleType.EQUILATERAL
    elif a == b or b == c:
        return TriangleType.ISOSCELES
    else:
        return TriangleType.SCALENE
```

Harder Oracles

Making Oracles Hard

- Results may differ by small epsilons (due to rounding)
- Expected result may not be computable without program
- May have time series results
- Takes a long time to manually compute each oracle (even when we can)
- Programs may be stochastic (or non-deterministic)

Examples

Note: The behavior of `round()` for floats can be surprising: for example, `round(2.675, 2)` gives `2.67` instead of the expected `2.68`. This is not a bug: it's a result of the fact that most decimal fractions can't be represented exactly as a float. See Floating Point Arithmetic: Issues and Limitations for more information.

Same growth values?

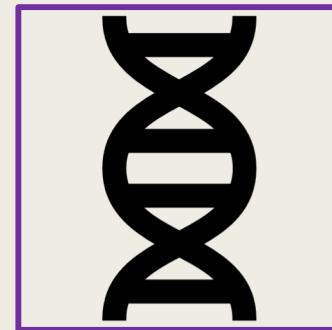| Expected:	0.35695124
Observed:	0.35695122

Correct hits?

Some Techniques

Differential testing

Metamorphic testing

Differential Testing
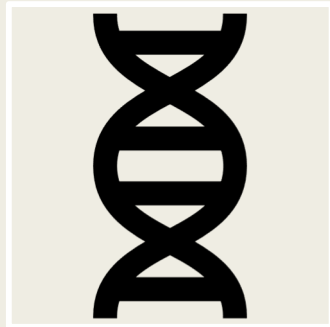
Run same tests using different programs that have the same functionality

➤ run tests with BLAST
➤ run tests with HPC-BLAST

Differential testing

Challenge is determining equivalency

Metamorphic Testing
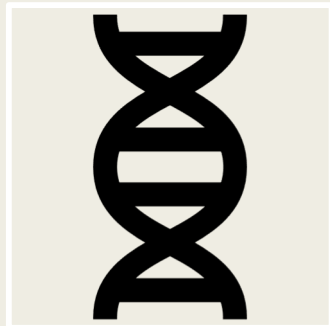

Metamorphic testing

Define relations on sets of tests:

e.g. (subtraction)

(1) A-B = C

Create A' (greater than A)

(2) A' -B = C'   means C' is greater than C

Metamorphic Testing

Metamorphic testing

Use Domain Knowledge
e.g. Ocean temperature modeling
A.   *Compute predicted temperature*
B.   *Modify to increase expected temperature*

Confirm relation holds

kbase-all-hands-on
v1 - KBaseFBA.FBA-13.2

| | Overview | Reaction fluxes | Exchange fluxes | Genes | Biomass | Pathways | Bar charts |

ID	myracohen:narrative_150
Object type	KBaseFBA.FBA-13.2
Owner	myracohen
Version	1
Mod-date	2024-02-26T06:15:44+0
Objective value	0.507834
Model	E-Coli_k12_MG1
Media	Carbon-D-Glucose
Single KO	0
Number reactions	857
Number compounds	29
Gene KO	0
Reaction KO	0
Custom bounds	0

kbase-all-hands-on-different-media
v2 - KBaseFBA.FBA-13.2

| | Overview | Reaction fluxes | Exchange fluxes | Genes | Biomass | Pathways | Bar charts |

ID	myracohen:narrative_1501886992034/kbase-all-hands-on-different-media
Object type	KBaseFBA.FBA-13.2
Owner	myracohen
Version	2
Mod-date	2024-02-26T06:36:45+0000
Objective value	13.4555
Model	E-Coli_k12_MG1
Media	Complete
Si... KO	0
	857
Number compounds	29
Gene KO	0
Reaction KO	0
Custom bounds	0

Carbon-D-Glucose <= Complete

Summary

- Two techniques that can be used when we lack oracles are Differential and Metamorphic Testing.

- Differential testing compares the outputs from two different applications that are expected to have the same functionality

- Metamorphic testing defines relations between sets of test cases

- Neither of these is as strong as having an exact oracle but they can be used to provide proxies for correctness.

Differential and Metamorphic Testing

Motivation

Differential
Testing

Metamorphic
Testing