



METAMORPHIC AND DIFFERENTIAL TESTING

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OF SCIENCE AND TECHNOLOGY

Laboratory for Variability-Aware Assurance and
Testing of Organic Programs



Overview



Motivation

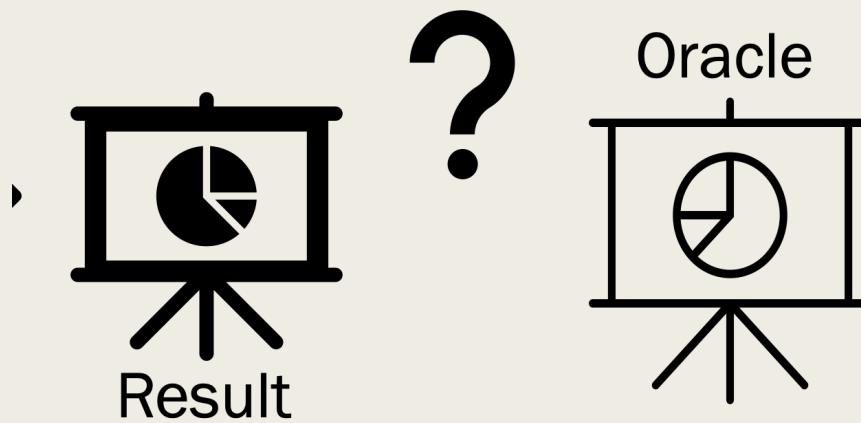


Differential
Testing



Metamorphic
Testing

What is the Correct Answer?



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

MEGA HIT Assemble Reads with MEGAHIT v1.1.1
Assemble metagenomic reads using the MEGAHIT assembler.

Run Configure Job Status Result

Input Objects

Read Library rhodo.art.q20.PE.reads

Parameters (5 advanced parameters showing) [hide advanced](#)

Parameter preset

--min-count

--k-min 1 ≤ ≤127

--k-max 1 ≤ ≤255

--k-step 1 ≤ ≤28

--k-list +

--min-contig-len 300 ≤ 2000

Output Objects

Output Assembly name



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

Python docs

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

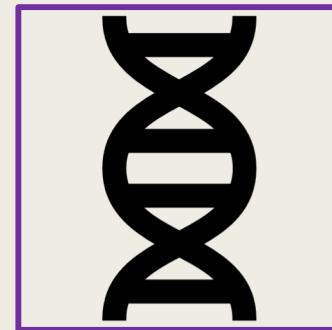
Correct hits?

Descriptions	Graphic Summary	Alignments	Taxonomy						
Sequences producing significant alignments									
		Download	Select columns	Show	100	?			
<input checked="" type="checkbox"/> select all 100 sequences selected									
GenBank Graphics Distance tree of results MSA Viewer									
	Description	Scientific Name	Max Score	Total Score	Query Cover	E value	Per. Ident	Acc. Len	Accession
<input checked="" type="checkbox"/>	Saccharomyces pastorianus strain CBS 1483 chromosome ScXII	Saccharomyc...	1040	1040	100%	0.0	100.00%	1135585	CP048993.1
<input checked="" type="checkbox"/>	Saccharomyces cerevisiae strain CEN.PK113-7D chromosome XII	Saccharomyc...	1040	1040	100%	0.0	100.00%	1032974	CP046092.1
<input checked="" type="checkbox"/>	Saccharomyces cerevisiae strain ySR128 chromosome XII, complete sequence	Saccharomyc...	1040	1040	100%	0.0	100.00%	1076801	CP036478.1
<input checked="" type="checkbox"/>	Saccharomyces cerevisiae strain Y169 chromosome 12	Saccharomyc...	1040	1040	100%	0.0	100.00%	1061690	CP033481.1

Some Techniques



Differential testing



Metamorphic testing

Differential Testing



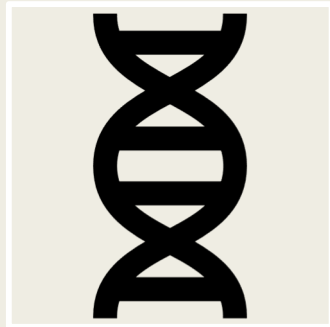
Differential testing

Run same tests using different programs that have the same functionality

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

Challenge is determining equivalency

Metamorphic Testing



Metamorphic testing

Define relations on sets of tests:

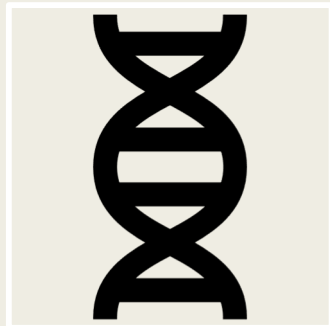
e.g. (subtraction)

(1) $A - B = C$

Create A' (greater than A)

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

Metamorphic Testing



Use Domain Knowledge

e.g. Ocean temperature modeling

A. Compute predicted temperature

B. Modify to increase expected temperature

Confirm relation holds

Metamorphic testing



kbse-all-hands-on

v1 - KBaseFBA.FBA-13.2

Overview

Reaction fluxes

Exchange fluxes

Genes

Biomass

Pathways

Bar charts

ID	myracohen:narrative_1501886992034/kbase-all-hands-on
Object type	KBaseFBA.FBA-13.2
Owner	myracohen
Version	1
Mod-date	2024-02-26T06:15:44+0000
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



kbse-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
Single KO	0
Number reactions	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

This work was supported by the Better Scientific Software Fellowship Program, funded by the Exascale Computing Project (17-SC-20-SC), a collaborative effort of the U.S. Department of Energy (DOE) Office of Science and the National Nuclear Security Administration; and by the National Science Foundation (NSF) under Grant No. 2154495.

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