



Software Testing

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- 2. Unit Test
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Introduction to Software Testing

Software Testing

An investigation conducted to provide stakeholders with information about the quality of the software under test (SUT)

- Software quality attributes
 - Correctness (Functionality)
 We will focus on this!
 - ☐ The software behaves exactly as intended according to its specifications
 - Performance
 - ☐ The software meets some performance-related expectations (execution time, network throughput, memory usage)
 - Usability
 - □ The software is easy to learn and use (intuitive user interfaces)
 - Reliability
 - The software performs well under various conditions and for a specific period



Why is Software Testing Important?

Even a small & trivial bug can cause big damage

Ariane 5^[1]

- The Ariane 5 rocket, developed by the European Space Agency, exploded just 40 seconds after launch
- The failure was caused by an integer overflow
- This small error resulted in the loss of the rocket and cargo worth around 600 million euros





Why is Software Testing Important?

Even a small & trivial bug can cause big damage

- Toyota Recall^[2]
 - 625,000 hybrid cars recalled in 2015 due to a software glitch in the braking system





Introduction

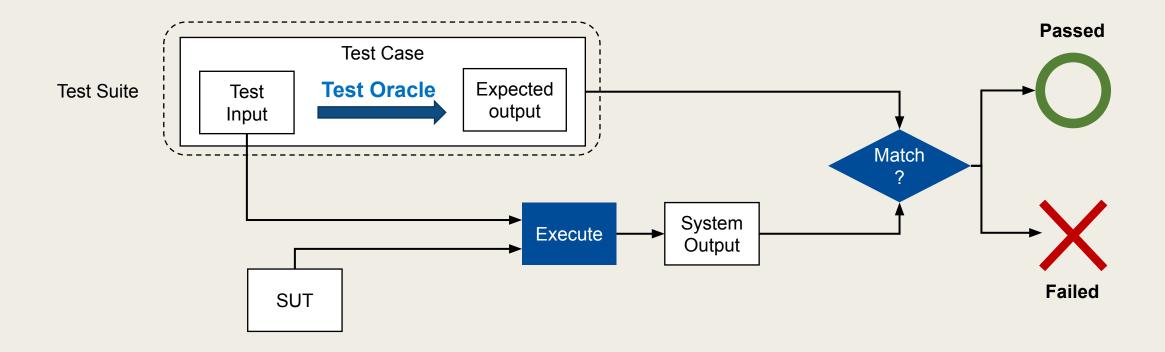
Software Testing Terminology

- **Test Input**: a set of input values that are used to execute the given program
- **Test Oracle**: a provider of the expected output based on the test input
- **Test Case:** test input + expected output
- Test Suite: a collection of test cases



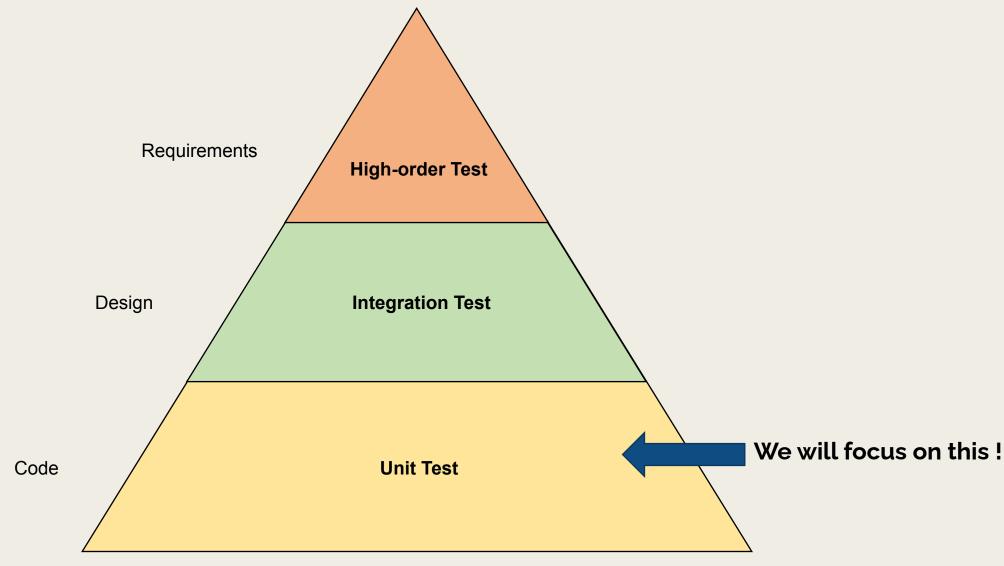
Process of Software Testing

Check whether the system's output and the expected output are the same





Software Testing Hierarchy







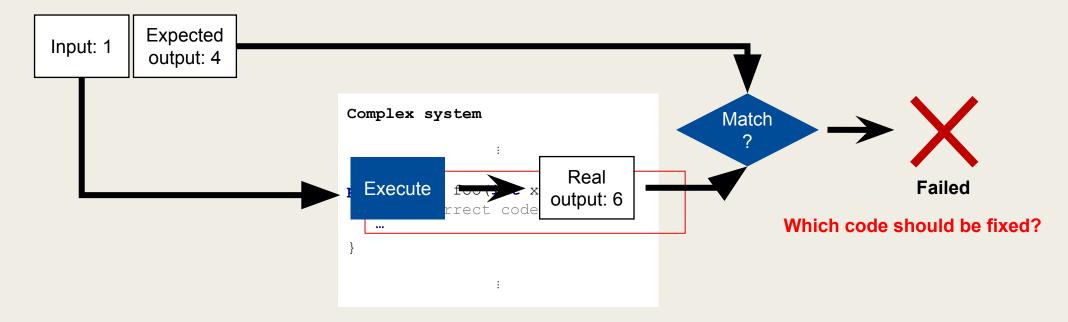


Unit Testing (Python)

Why Unit Test?

Test each unit (function, class) of the software to check whether they satisfy the requirements

□ Detect bugs early and ensure each unit works correctly in isolation





SUT in This Tutorial

Basic requirements of a car

A car tracks its driving time, distance, and speed.

A car can change its speed.

A car should be able to return its current speed and average speed.

- Based on the requirements, the following code can be written
- □ car.py (See Appendix A)

```
class Car:
    def __init__(self, speed=0):
        self.speed = speed
        self.odometer = 0
        self.time = 0

    def change_speed(self, change):
        ...
    def get_current_speed(self):
        ...
    def average_speed(self):
        ...
```



Writing and Running Test Cases

- Based on the SUT, unit test code can be written

 test_car.py (Appendix B)
 - Specify test input to get the real output
 - Specify the expected test output
 - Compare the real output and expected output

```
import pytest
import random
from car import Car

@pytest.fixture
def car():
    return Car()

def test_initial_speed(car):
    assert car.speed == 0
```

- Run test cases
 - pytest <test_file>
 - Ex) pytest test_car.py



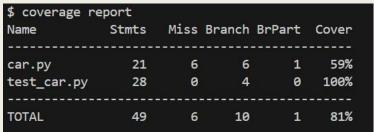
Checking Test Coverage

Test coverage

- How much of the source code is executed by the test suite
 - Statement coverage
 - Branch coverage
- High coverage generally leads to more reliable and robust software
- However, 100% coverage does not guarantee 100% correctness
- ☐ Coincidental correctness: quality of test cases also matters

Check test coverage

- coverage run -branch -m pytest test car.py
- · coverage report





Unit Testing

Tutorial Setting

Install Python 3.10.11

https://www.python.org/downloads/release/python-31011/

Windows installer (64-bit) Windows Recommended a55e9c1e6421c84a4bd8b4be41492f51 27.7 MB SIG .sigstore

- Confirm git installation
 - Open Powershell
 - Try git version
- If error, install git

https://github.com/git-for-windows/git/releases/tag/v2.49.0.windows.1

Git-2.49.0-64-bit.exe

726056328967f242fe6e9afbfe7823903a928aff577dcf6f517f2fb6da6ce83c



Unit Testing

Tutorial Setting

 Fork the tutorial repository from the URL below <u>https://github.com/kaist-webeng/software-testing-exercise</u>

- Clone your forked repository
 - git clone <a href="https://github.com/<your ID>/software-testing-exercise">https://github.com/<your ID>/software-testing-exercise
- Install the required python packages (required python version: 3.10)
 - pip install –r requirements.txt



Challenges of Generating Test Cases

Exhaustive Testing

- Can we test all possible test inputs?
 - Ex) Password Checker: checks 8-character passwords using only uppercase letters $(A-Z) \square$ There are 26⁸ = 208,827,064,576 possible combinations
- All test inputs need to be executed & the result should be compared with expected result

 prohibitive cost

Small & effective test suite

- Testing allows only a sampling of an enormously large program input space
- The difficulty lies in how to come up with effective sampling



Challenges of Generating Test Cases

Quality of test suite

- A high-quality test suite ensures high coverage and includes edge cases that can reveal the faults
- However, manually writing such test cases is time-consuming and error-prone
- Automated test generation tools
 - Create high-coverage, effective test cases without human effort







Automated Test Case Generation

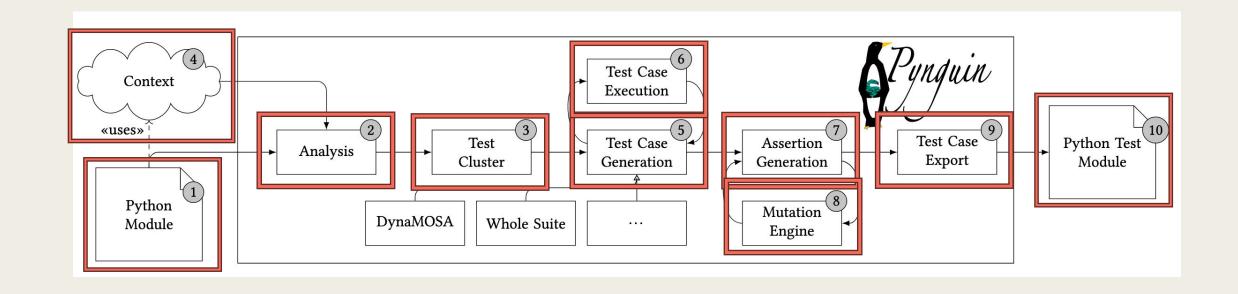
What is Pynguin?

- PYthoN General UnIt Test generator[1, 2]
 - A tool that allows developers to generate unit tests automatically.
- Mature tools exist for statically typed languages like Java
 - No comprehensive tool existed for dynamically typed languages like Python
- Pynguin steps in as the first tool to enable fully-automated generation





Execution Steps of Pynguin





Going Back Inside Our Car

Pynguin requires setting env var^[3]:

```
export PYNGUIN_DANGER_AWARE=x
```

 Provide pynguin with source and output paths:

```
$ pynguin --project-path .
--output-path pynguin-results
--module-name car
```

Check your generated test file!

```
class Car:
    def __init__(self, speed=0):
        self.speed = speed
        self.odometer = 0
        self.time = 0

    def change_speed(self, change):
        ...
    def get_current_speed(self):
        ...
    def average_speed(self):
        ...
```

```
$ coverage report

Name Stmts Miss Branch BrPart Cover

car.py 21 6 6 1 59%

test_car.py 28 0 4 0 100%

TOTAL 49 6 10 1 81%
```

Test Generation

Pynguin Results

```
1 # Test cases automatically generated by Pynguin (https://www.pynguin.eu).
   # Please check them before you use them.
    import pytest
    import car as module_0
                                    The test is expected to fail!
    @pytest.mark.xfail(strict=True)
   def test_case_0():
       bool_0 = False
       car_0 = module_0.Car()
10
       assert car_0.speed = 0
11
       assert car_0.odometer = 0
       assert car_0.time = 0
13
       var_0 = car_0.change_speed(bool_0)
       assert car_0.time = 1
       var_0.step()
    def test_case_1():
       none_type_0 = None
       car_0 = module_0.Car(none_type_0)
21
       assert car_0.odometer = 0
       assert car_0.time = 0
       with pytest.raises(Exception):
           car_0.average_speed()
27
    def test_case_2():
29
       car_0 = module_0.Car()
       assert car_0.speed = 0
       assert car_0.odometer = 0
       assert car_0.time = 0
```

\$ coverage repo Name S	rt tmts	Miss	Branch	BrPart	Cover
car.py test_car.py	21 28	6 0	6 4	1 0	59% 100%
TOTAL	49	6	10	1	81%

VS

Name	Stmts	Miss	Branch	BrPart	Cover
car.py test_car.py	21 75	0 U] 6	 0 0	100% 100%
TOTAL	96	0	6	0	100%





Automated Continuous Integration

Automated Continuous Integration

- Continuous Integration (CI): a development practice where developers
 frequently integrate code into a shared repository
- Automated CI enables that code changes are automatically built, tested, and validated each time they are committed
- ☐ It is essential for fast and error-free integration of the code

CI tools

GitHub Actions



Actions

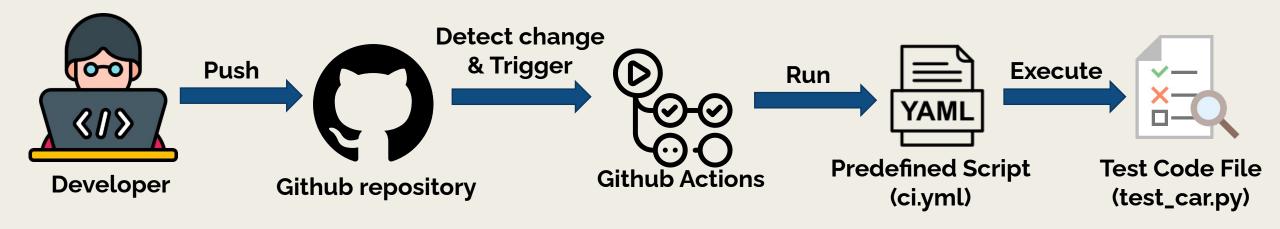
Jenkins





Github Action

- When a developer pushes the changed code, GitHub Actions automatically run a predefined script that executes test code
- ☐ Our predefined script: ci.yml (See Appendix F)





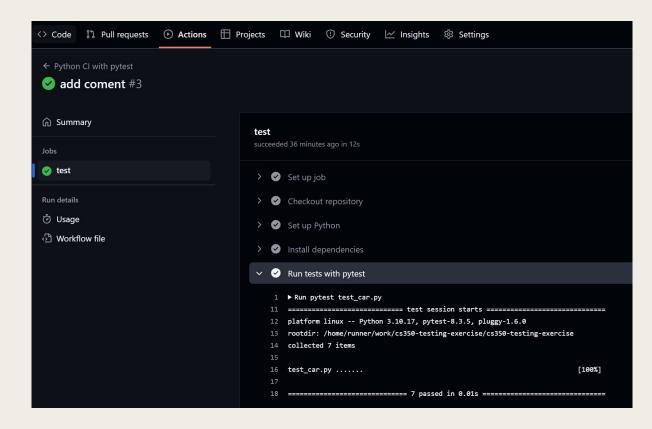
CI

Github Action

Add your CI script (ci.yml) to below path

<root directory>/.github/workflows

- Change your source code (car.py)
- Push your new commit
- Check your predefined script for CI is automatically executed









Thank you

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Appendix

- A. Source Code car.py
 - B. Sample Test Code test_car.py
 - C. Source Code lift.py
 - D. Sample Test Code test_lift.py
 - C. Generated Test Code pynguin-results/test_car.py

Source Code - car.py

```
class Car:
    def __init__(self, speed=0):
        self.speed = speed
        self.odometer = 0
        self.time = 0
   def change_speed(self, change):
        if change < 0:</pre>
           if self.speed + change < 0:</pre>
                self.speed = 0
           else:
                self.speed += change
        else:
            self.speed += change
        self.step()
    def get_current_speed(self):
        return self.speed
    def step(self):
        self.odometer += self.speed
        self.time += 1
    def average_speed(self):
        if self.time == 0:
            raise Exception("Divide by 0! Car did not move!")
        else:
            return self.odometer / self.time
```



Sample Test Code - test_car.py

```
import pytest
import random
from car import Car
@pytest.fixture
def car():
    return Car()
def test initial speed(car):
    assert car.speed == 0
def test initial odometer(car):
    assert car.odometer == 0
def test_initial_time(car):
    assert car.time == 0
```

```
# Tests for changing speed
def test_change_speed(car):
    car.change_speed(7)
    assert car.speed == 7
def test_multiple_speed_change(car):
    total_change = 0
    random.seed(42)
    for _ in range(3):
        change = random.randint(0, 10)
        total_change += change
        car.change_speed(change)
    assert car.speed == total_change
# Tests for getting current speed
def test_get_current_speed_from_start(car):
    assert car.get current speed() == 0
def test_get_current_speed_after_change(car):
    car.change_speed(27)
    assert car.get_current_speed() == 27
```



Sample Test Code - lift.py

```
class Lift:
  def init (self, highest floor, max riders =10):
       self.top floor = highest floor
      self.current floor = 0
       self.capacity = max riders
  def get top floor (self):
       return self.top floor
  def get current floor (self):
       return self.current floor
  def get capacity (self):
       return self.capacity
  def get num riders (self):
  def is full(self):
       return self.num riders == self.capacity
```

```
def add riders (self, num entering):
    if self.num riders + num entering <= self.capacity:</pre>
        self.num riders += num entering
        self.num riders = self.capacity
def go up(self):
    if self.current floor < self.top floor:</pre>
        self.current floor += 1
def go down(self):
    if self.current floor > 0:
        self.current floor -= 1
def call(self, floor):
    if 0 <= floor <= self.top floor:</pre>
        while self.current floor != floor:
            if floor > self.current floor:
                self.go up()
            else:
                self.go down()
```



Sample Test Code – test_lift.py

```
import pytest
from lift import Lift
  lift = Lift(5)
  assert lift.get top floor() == 5
   assert lift.get current floor() == 0
  assert lift.get num riders() == 0
   assert not lift.is full()
  lift = Lift(5)
  lift.add riders(5)
   assert lift.get num riders() == 5
  assert not lift.is full()
  lift = Lift(3)
  lift.go up()
  lift.go up()
  lift.go up() # should be at top
  lift.go up() # should stay at top
   assert lift.get current floor() == 3
```



Appendix E

Generated Test Code - pynguin-results/test_car.py

```
# Test cases automatically generated by Pynguin
(https://www.pynguin.eu).
# Please check them before you use them.
import pytest
import car as module 0
def test case 0():
   float 0 = -13.59933065467643
   car 0 = module 0.Car()
   assert car 0.speed == 0
   assert car 0.odometer == 0
   assert car_0.time == 0
   var_0 = car_0.change_speed(float_0)
   assert car 0.time == 1
@pytest.mark.xfail(strict=True)
def test case 1():
   bool 0 = False
   car 0 = module 0.Car()
   assert car 0.speed == 0
   assert car 0.odometer == 0
   assert car 0.time == 0
   var 0 = car 0.change speed(bool 0)
   assert car 0.time == 1
   var 0.step()
def test case 2():
   float 0 = -35.84348955890579
   car 0 = module 0.Car()
   assert car_0.speed == 0
   assert car 0.odometer == 0
   assert car 0.time == 0
   var 0 = car 0.change speed(float 0)
   assert car_0.time == 1
   car 1 = module 0.Car()
   assert car 1.speed == 0
   assert car 1.odometer == 0
   assert car 1.time == 0
   car 2 = module 0.Car()
   assert car 2.speed == 0
   assert car_2.odometer == 0
   assert car 2.time == 0
   with pytest.raises(Exception):
       car 2.average speed()
```

```
@pytest.mark.xfail(strict=True)
def test case 3():
   float_0 = -12.76562758095508
   car 0 = module 0.Car()
   assert car 0.speed == 0
   assert car 0.odometer == 0
   assert car 0.time == 0
   var 0 = car 0.change speed(float 0)
   assert car 0.time == 1
   car 1 = module 0.Car()
   assert car_1.speed == 0
   assert car 1.odometer == 0
   assert car 1.time == 0
   var_1 = car_0.average_speed()
   assert var 1 == pytest.approx(0.0, abs=0.01, rel=0.01)
   var 0.change speed(car 1)
def test case 4():
   car 0 = module 0.Car()
   assert car 0.speed == 0
   assert car 0.odometer == 0
   assert car 0.time == 0
@pytest.mark.xfail(strict=True)
def test case 5():
   car 0 = module 0.Car()
   assert car_0.speed == 0
   assert car 0.odometer == 0
   assert car 0.time == 0
   var 0 = car 0.step()
   assert car_0.time == 1
   var 1 = car 0.get current speed()
   assert var 1 == 0
   car_0.change_speed(car_0)
```

```
@pytest.mark.xfail(strict=True)
def test case 6():
   car_0 = module_0.Car()
   assert car 0.speed == 0
   assert car 0.odometer == 0
   assert car 0.time == 0
   var 0 = car 0.step()
   assert car 0.time == 1
   var 0.step()
@pytest.mark.xfail(strict=True)
def test case 7():
   float_0 = -0.23206040601398698
   car 0 = module 0.Car()
   assert car 0.speed == 0
   assert car 0.odometer == 0
   assert car 0.time == 0
   var 0 = car 0.change speed(float 0)
   assert car 0.time == 1
   bool 0 = True
   var 1 = car 0.change speed(bool 0)
   assert car 0.speed == 1
   assert car 0.odometer == 1
   assert car 0.time == 2
   var 2 = car 0.get current speed()
   assert var 2 == 1
   var 3 = car 0.change speed(float 0)
   assert car_0.speed == pytest.approx(0.767939593986013, abs=0.01, rel=0.01)
   assert car 0.odometer == pytest.approx(1.767939593986013, abs=0.01, rel=0.01)
   assert car 0.time == 3
   car 0.change speed(var 1)
```



CI Script - ci.yml

```
name: Python CI with pytest
 push:
 pull request:
jobs:
 test:
   runs-on: ubuntu-latest
    - name: Checkout repository
       uses: actions/checkout@v4
     - name: Set up Python
       uses: actions/setup-python@v5
         python-version: "3.10"
     - name: Install dependencies
        python -m pip install --upgrade pip
        pip install -r requirements.txt
     - name: Run tests with pytest
        pytest test car.py
```







EOF