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IIT Madras
BSc Degree

Testing

Application Testing

- Why?
- What?
- When?
- How?
- Pytest

Why?

Does *something* work *as intended*

- Requirements - specifications
- Respond correctly to inputs
- Respond within reasonable time
- Installation and environment
- Usability and Correctness

Static vs. Dynamic

Static Testing:

- Code review, correctness proofs

Dynamic Testing:

- Functional tests
- Apply suitable inputs

White-box testing

- Detailed knowledge of implementation
- Can examine internal variables, counters
- Tests can be created based on knowledge of internal structure
- Pro:
    - More detailed information available, better tests
- Con:
    - Can lead to focusing on less important parts because code is known
    - Does not encourage clean abstraction
    - Too much information?

Black-box testing

- Only interfaces are available, not the actual code
- Tests based on how it would look from outside
- Pro:
    - Closer to real usage scenario
    - Encourages (enforces) clean abstraction of interface
- Con:
    - May miss corner cases that would have been obvious if internal structure was known
    - Debugging is harder - even if it failed, why did it fail?

Grey-box testing

- Hybrid approach between white-box and black-box
- Enforce interface as far as possible
- Internal structure mainly used for debugging, examining variables etc.

Regressions

- Maintain series of tests starting from basic development of code
    - Each test is for some specific feature or set of features
- **Regression**: loss of functionality introduced by some change in the code
- Future modifications to code should not break existing code
- Sometimes necessary
    - Update tests
    - Update API versions etc.

Coverage

- How much of the code is covered
  - Every line is executed at least once - 100% code coverage
  - Does not guarantee “correctness” in all conditions
  - There may be more complex paths or other conditions that can cause failure
- Branch coverage, condition coverage, function coverage ...

Example

```c
int foo (int x, int y)
{
    int z = 0;
    if ((x > 0) && (y > 0))
    {
        z = x;
    }
    return z;
}
```

Src: Wikipedia

Example

```
int foo (int x, int y)
{
    int z = 0;
    if ((x > 0) && (y > 0))
    {
        z = x;
    }
    return z;
}
```

Src: Wikipedia

Function coverage

- Test invokes foo() at least once

Example

```
int foo (int x, int y)
{
    int z = 0;
    if ((x > 0) && (y > 0))
    {
        z = x;
    }
    return z;
}
```

Src: Wikipedia

Statement coverage

- Example: foo(1,1)
    - All statements in code will be executed

Example

```
int foo (int x, int y)
{
    int z = 0;
    if ((x > 0) && (y > 0))
    {
        z = x;
    }
    return z;
}
```

Src: Wikipedia

Branch coverage

- At least two tests needed:
- foo(1,1)
  - Branch taken
- foo(1,0)
  - Branch not taken

Example

```
int foo (int x, int y)
{
    int z = 0;
    if ((x > 0) && (y > 0))
    {
        z = x;
    }
    return z;
}
```

Src: Wikipedia

Condition coverage

- At least two tests needed:
- foo(0,1)
  - First condition fails, second succeeds
- foo(1,0)
  - First condition succeeds, second fails
- Note: does not guarantee branch coverage

Summary

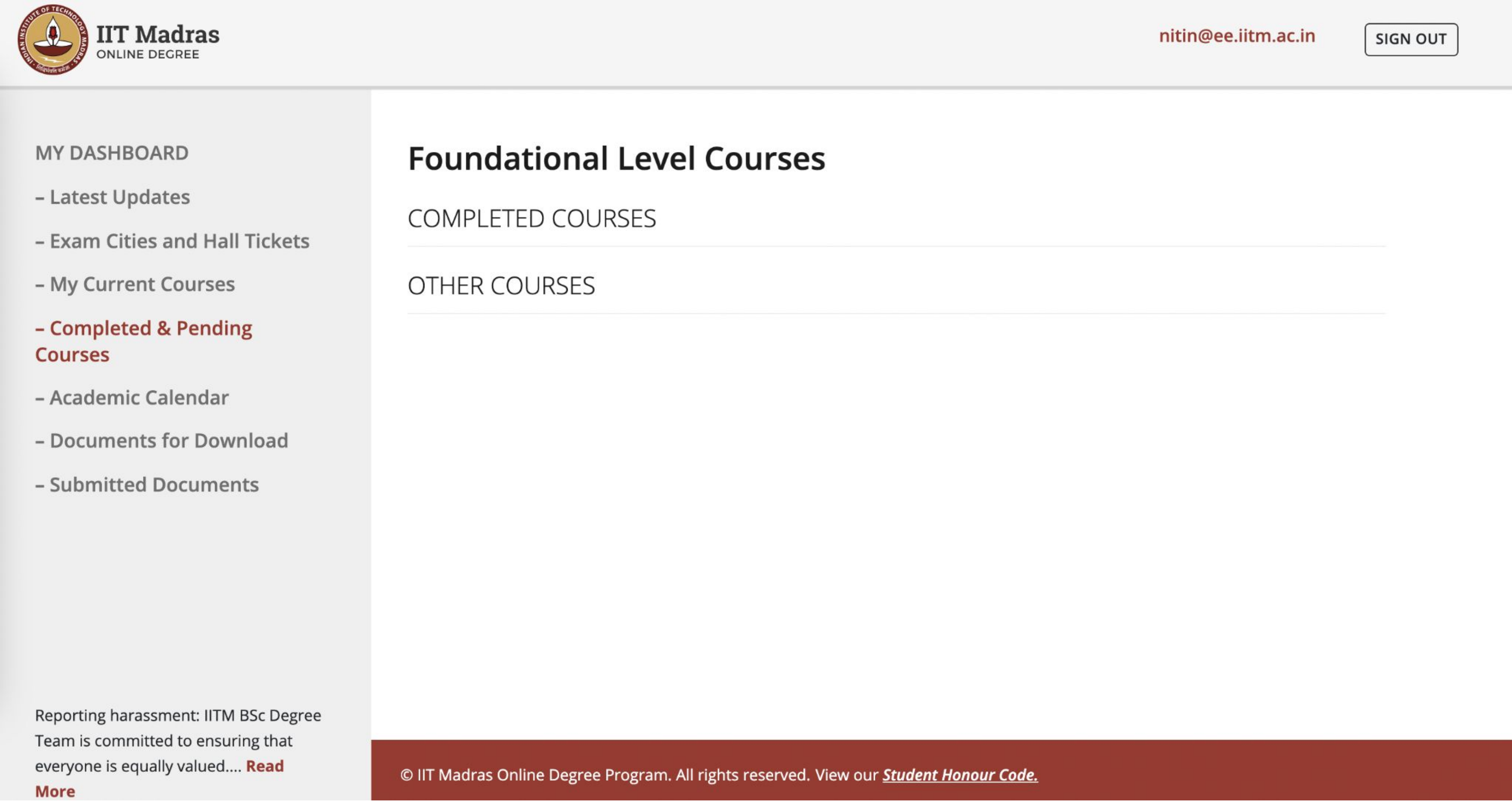
- Requirements specified by user
- Creating suitable tests can itself be challenging
- How much knowledge of the code internals should the tester have?
- Separation of concerns:
  - ideally tester should be able to generate test cases based only on spec and without knowing code
- Code coverage useful metric
  - Does not guarantee all scenarios actually tested!

Levels of Testing

Example: Onlinedegree dashboard

Initial requirements gathering

- Who are the stakeholders?
    - Students - log in and see courses
    - Admins - manage students
    - Teachers - update / manage course material ?
- Functionality
    - Each group has different needs
- Non-functional requirements
    - Page colour, font, logo



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Example: Student page

Functional

- Latest updates
- Register exam hall preferences
- Download hall ticket
- Update course registration
- View completed courses
- . . .

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Functional

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- Register exam hall preferences
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Non-functional

- Header / Footer colours
- Copyright notice and extra information
- Logo
- Fonts
- . . .

Requirements gathering

- Extensive discussions with end-users required
- Avoid language ambiguity
- Capture use cases and *examples*
- Start thinking about test cases and how the requirements will be validated

Units of Implementation

- Break functional requirements down to small, implementable ***units***
- Examples:
  - view course list
  - edit course status
  - edit exam preferences
  - download completion certificate
- Each one may become a single controller
  - May also combine multiple into a single controller

Unit Testing

- Test each individual unit of implementation
- May be single controllers
  - May even be part of a controller
- Clearly define inputs and expected outputs
- Testable in isolation?
  - Can each unit be tested without the entire system?
  - Create artificial data set to check whether a single update works

Example: Unit tests

Student registers for a course

- Create dummy DB:
  - One student
  - One course
- Test
  - Controller to add course for student
  - Form to be displayed
  - Invalid student ID, course ID - error codes?
  - Add student more than once?

Integration

- Application consists of multiple modules:
  - Student management
  - Course management
  - Payment interfaces
  - Admin interface

Integration Testing

- Example of integration:
  - Student + Payment gateway
  - Student + Course + Admin
  - All of the above . . .
- Potential problems:
  - Individual units work - combined system does not
  - Dependencies violations in server - redesign?
- Continuous integration
  - Combined with version control systems: CI
  - Each commit to main branch triggers a re-evaluation of integration tests
  - Multiple times a day possible

System-level Testing

- One step beyond integration
- Includes server, environment
- Mainly black-box: should validate final usage

Example: onlinedegree

- Deploy on final environment: Google app-engine
- Test domains used
- Confirm all aspects of behaviour
- Non-functional tests:
    - Performance under load
    - Number of instances, scaling
    - Cost!

System testing Automation

- Has to simulate actual user interaction
- Browser automation frameworks
  - Selenium (example)
- Includes database, persistent connections etc.
- Typically a complete secondary system

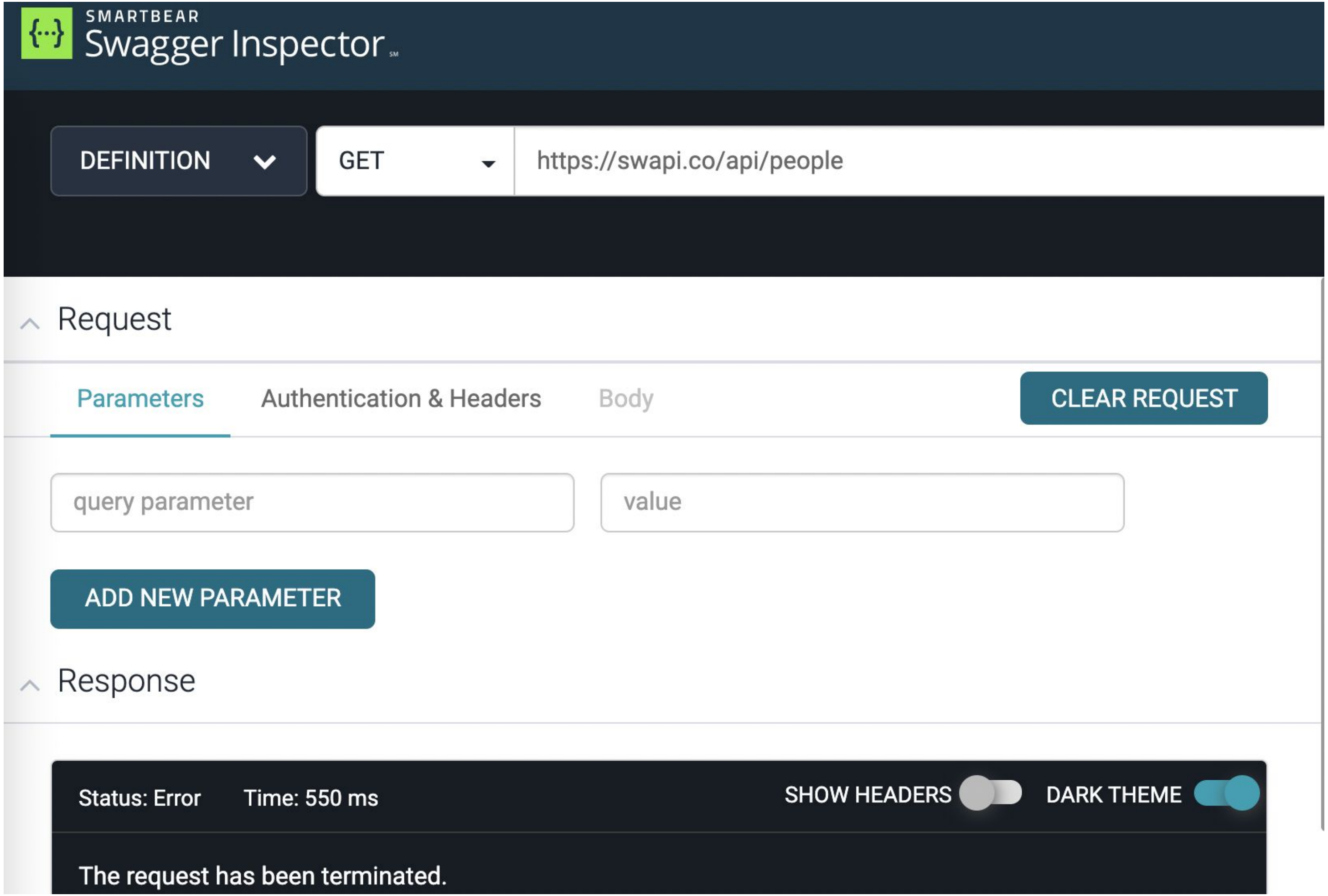
User Acceptance Testing

- Deploy final system
- Tested by restricted set of users - pilot
- “Beta” testing
  - Beta- software: pre-production

Test generation

API-based testing

- Application Programming Interface: abstraction for system design
- Standard representations for APIs
  - OpenAPI, Swagger etc.
- Can they also generate test cases?



GET https://swapi.co/api/people

Status: Error Time: 550 ms

The request has been terminated.

Use cases

- Import API definition from standard like OpenAPI
- Generate tests for specific endpoints, scenarios
- Record API traffic
- Inject possible problem cases based on known techniques
- Data validation tests

Abstract Tests

- Semi-formal verbal description:
    - Make a request to ‘/’ endpoint
    - Ensure that result contains text “Hello world”

Abstract Tests

- Semi-formal verbal description:
  - Make a request to ‘/’ endpoint
  - Ensure that result contains text “Hello world”

```python
def test_hello(client):
    """Verify home page."""

    rv = client.get('/')
    assert b'Hello world' in rv.data
```

Model-based testing

Example: Authenticate user before showing information

- Scenarios:
  - User already logged in - page shown
  - User not yet logged in - redirect to login page
  - Forgot password - after resetting, come back to desired page
- Model:
  - Possible states (logged in, password reset, ...)
  - Possible transitions
  - Generate tests for the possible transitions

Models and Abstract Tests

- Abstract tests apply to generic models
- Create model for system-under-test
- Derive “executable” tests by combining abstract test information with model

(G)UI testing

- User interface: visual output
- Usually GUI - even for web-based systems
  - But specific details of graphical display may be different in web-based systems
- Tests:
  - Are specific elements present on page
  - Are navigation links present
  - What happens on random click on some part of the page

Browser automation

- Some tests cannot be directly run programmatically
  - Browser is **required**, just requests not sufficient
- Example:
  - IRCTC or SBI website - captcha protected
  - Some user input also required - cannot be completely automated
- Request generation:
  - Python requests library
  - Capybara (ruby), ...
- Direct browser automation:
  - Selenium framework - actually instantiate a browser

Security testing

- Generate invalid inputs to test app behaviour
- Try to crash server - overload, injection etc.
- Black-box or White-box approaches
- **Fuzzing** or Fuzz-testing:
  - Generate large number of random/semi-random inputs

pytest

What?

- Framework to make testing easier in Python
- Opinionated:
    - Provides several defaults to make it easier to write tests
- Helpful features:
    - Can automatically set up environment, tear down after test etc.
    - Test fixtures, monkeypatching etc.

Note: python standard library includes `unittest` - pytest is an alternative with some more features

Example

```python
# content of test_sample.py
def func(x):
    return x + 1

def test_answer():
    assert func(3) == 5
```

Example

```python
# content of test_sample.py
def func(x):
    return x + 1

def test_answer():
    assert func(3) == 5
```

```
$ pytest
================ test session starts ======================
platform linux -- Python 3.x.y, pytest-6.x.y, py-1.x.y,
pluggy-1.x.y
cachedir: $PYTHON_PREFIX/.pytest_cache
rootdir: $REGENDOC_TMPDIR
collected 1 item

test_sample.py F
[100%]

================ FAILURES =================================
________________________________ test_answer ______________

    def test_answer():
>       assert func(3) == 5
E       assert 4 == 5
E        +  where 4 = func(3)

test_sample.py:6: AssertionError
================ short test summary info ==================
FAILED test_sample.py::test_answer - assert 4 == 5
================ 1 failed in 0.12s ========================
```

Test for exceptions

```python
# content of test_sysexit.py
import pytest


def f():
    raise SystemExit(1)


def test_mytest():
    with pytest.raises(SystemExit):
        f()
```

Temporary directory etc.

```
# content of test_tmpdir.py
def test_needsfiles(tmpdir):
    print(tmpdir)
    assert 0
```

Temporary directory etc.

```python
# content of test_tmpdir.py
def test_needsfiles(tmpdir):
    print(tmpdir)
    assert 0
```

```
$ pytest -q test_tmpdir.py
F                                                                  [100%]
================================= FAILURES =================================
_____________________________ test_needsfiles ______________________________

tmpdir = local('PYTEST_TMPDIR/test_needsfiles0')

    def test_needsfiles(tmpdir):
        print(tmpdir)
>       assert 0
E       assert 0

test_tmpdir.py:3: AssertionError
--------------------------- Captured stdout call ---------------------------
PYTEST_TMPDIR/test_needsfiles0
========================= short test summary info ==========================
FAILED test_tmpdir.py::test_needsfiles - assert 0
1 failed in 0.12s
```

Test Fixtures

- Set up some data before test
- Remove after test
- Examples:
  - initialize dummy database
  - Create dummy users, files

Example: test fixture

```python
import pytest

@pytest.fixture
def setup_list():
    return ["apple", "banana"]

def test_apple(setup_list):
    assert "apple" in setup_list

def test_banana(setup_list):
    assert "banana" in setup_list

def test_mango(setup_list):
    assert "mango" in setup_list
```

Result: test fixture

```
test_fruit.py ..F                      [100%]

========== FAILURES =========================
__________ test_mango _______________________

setup_list = ['apple', 'banana']

    def test_mango(setup_list):
>       assert "mango" in setup_list
E       AssertionError: assert 'mango' in ['apple', 'banana']

test_fruit.py:14: AssertionError
========== short test summary info ==========
FAILED test_fruit.py::test_mango - AssertionError: assert 'mango' in
['apple', 'banana']
========== 1 failed, 2 passed in 0.01s ======
```

Conventions

- Test discovery starts from current dir or **`testpaths`** variable
  - Recurse into subdirectories unless specified not to
- Search for files name `test_*.py` or `*_test.py`
- From those files:
  - `test` prefixed test functions or methods outside of class
  - `test` prefixed test functions or methods inside `Test` prefixed test classes (without an `__init__` method)
- Also supports standard python `unittest`

Testing Flask applications

- Create a `client` fixture - known to Flask
- Set up dummy database, temp dir etc. in fixture
- Use `requests` library to generate queries

Fixture setup

```
import os
import tempfile

import pytest

from flaskr import create_app
from flaskr.db import init_db


@pytest.fixture
def client():
    db_fd, db_path = tempfile.mkstemp()
    app = create_app({'TESTING': True, 'DATABASE': db_path})

    with app.test_client() as client:
        with app.app_context():
            init_db()
        yield client

    os.close(db_fd)
    os.unlink(db_path)
```

Test example

```python
def test_empty_db(client):
    """Start with a blank database."""

    rv = client.get('/')
    assert b'No entries here so far' in rv.data
```

Testing login and other features

```
def login(client, username, password):
    return client.post('/login', data=dict(
        username=username,
        password=password
    ), follow_redirects=True)


def logout(client):
    return client.get('/logout', follow_redirects=True)
```

```python
def test_login_logout(client):
    """Make sure login and logout works."""

    username = flaskr.app.config["USERNAME"]
    password = flaskr.app.config["PASSWORD"]

    rv = login(client, username, password)
    assert b'You were logged in' in rv.data

    rv = logout(client)
    assert b'You were logged out' in rv.data

    rv = login(client, f"{username}x", password)
    assert b'Invalid username' in rv.data

    rv = login(client, username, f'{password}x')
    assert b'Invalid password' in rv.data
```

Evaluation

```
import pytest
import os.path

class TestWeek1PublicCases:
    # Test case to check if the contact.html file exists
    def test_public_case1(self, student_assignment_folder):
        file_path = student_assignment_folder + "contact.html"
        assert os.path.isfile(file_path) == True

    # Test case to check if the resume.html file exists
    def test_public_case5(self, student_assignment_folder):
        file_path = student_assignment_folder + "resume.html"
        assert os.path.isfile(file_path) == True
```

Summary

- Automated testing is essential to get confidence in design
- Regression testing:
  - ensure previously passed tests do not start failing
- Test generation process:
  - mix of manual and automated

Continuous testing essential for overall system stability