CMPT 473
Software Testing, Reliability and Security

Intro to Testing

Nick Sumner
Why Do We Test?

- Recall: What role did testing play in the process we saw last time?
Why Do We Test?

- Recall: What role did testing play in the process we saw last time?
  - Measurement - Testing provides a metric of software quality
Why Do We Test?

- Recall: What role did testing play in the process we saw last time?
  - **Measurement** – Testing provides a metric of software quality
  - It gives us empirical confidence that software is acceptable
Why Do We Test?

- Recall: What role did testing play in the process we saw last time?
  - Measurement – Testing provides a metric of software quality

  e.g. for requirements / criteria R1, R2, R3, R4

  Each test T can check a requirement
Why Do We Test?

- Recall: What role did testing play in the process we saw last time?
  - Measurement – Testing provides a metric of software quality

E.g. for requirements / criteria R1, R2, R3, R4
Each test T can check a requirement

\[ T_1 \rightarrow R_1, R_2 \]
Why Do We Test?

- Recall: What role did testing play in the process we saw last time?
  - Measurement – Testing provides a metric of software quality

E.g. for requirements / criteria R1, R2, R3, R4
Each test T can check a requirement

\[
T_1 \rightarrow R_1, R_2 \quad \checkmark \\
T_2 \rightarrow R_3 \quad \checkmark 
\]
Why Do We Test?

- Recall: What role did testing play in the process we saw last time?
  - Measurement – Testing provides a metric of software quality

E.g. for requirements / criteria R1, R2, R3, R4
Each test T can check a requirement

\[
\begin{align*}
T_1 &\rightarrow R_1, R_2 & \checkmark \\
T_2 &\rightarrow R_3 & \checkmark \\
T_3 &\rightarrow R_4 & \times
\end{align*}
\]
But What is Testing?

*Reasoning* about behavior is hard/subtle.
But What is Testing?

Reasoning about behavior is hard/subtle.

Running a program is easy (easier)....
But What is Testing?

Reasoning about behavior is hard/subtle.

Running a program is easy (easier)....

**Testing** (informally):

Running the program to see if it behaves as expected
But What is Testing?

Reasoning about behavior is hard/subtle.

Running a program is easy (easier)....

Testing (informally):

Running the program to see if it behaves as expected

Simple idea, but...

- More than half of development cost
- Still cheaper than not testing
- Testing well is hard
Idea?

Run a program on all inputs:

```python
for test in allPossibleInputs:
    run_program(test)
```
Ideas?

Run a program on all inputs:

```python
for test in allPossibleInputs:
    run_program(test)
```

Why not?
Ideas?

Run a program on all inputs:

```python
for test in allPossibleInputs:
    run_program(test)
```

Why not?

Maybe select a few tests:

```python
import random.sample
for test in sample(allPossibleInputs, 100):
    run_program(test)
```
Ideas?

Run a program on all inputs:

```python
for test in allPossibleInputs:
    run_program(test)
```

Why not?

Maybe select a few tests:

```python
import random.sample
for test in sample(allPossibleInputs, 100):
    run_program(test)
```

Why not?
Ideas?

Run a program on all inputs:

```python
for test in allPossibleInputs:
    run_program(test)
```

Why not?

Maybe select a few tests:

```python
import random.sample
for test in sample(allPossibleInputs, 100):
    run_program(test)
```

Why not?

A primitive example of *fuzz testing*.
Need A Bit More Care

Testing:

- *Dynamically* examines (runs) a program
Testing:

- *Dynamically* examines (runs) a program
- Considers specific *software under test*
Testing:

- *Dynamically* examines (runs) a program
- Considers specific *software under test*
- Run *test cases* from a *test suite* that targets specific quality goals
Need A Bit More Care

Testing:

- *Dynamically* examines (runs) a program
- Considers specific *software under test*
- Run *test cases* from a *test suite* that targets specific quality goals
- Identifies differences between *observed behavior* and *expected behavior*
Need A Bit More Care

Testing:

- *Dynamically* examines (runs) a program
- Considers specific *software under test*
- Run *test cases from a test suite* that targets specific quality goals
- Identifies differences between *observed behavior and expected behavior*

We can use this framework to refine how we test
Targeting Quality Objectives

• **Functional**
  - Does the program provide expected output for a given input?
  e.g. ...
Targeting Quality Objectives

- **Functional**
  - Does the program provide expected output for a given input? e.g. Correct Output. All features present. Interface design.
Targeting Quality Objectives

- **Functional**
  - Does the program provide expected output for a given input?
    e.g. Correct Output. All features present. Interface design.

- **Nonfunctional**
  - Are output independent goals met?
    e.g. ...
Targeting Quality Objectives

- **Functional**
  - Does the program provide expected output for a given input?
    e.g. Correct Output. All features present. Interface design.

- **Nonfunctional**
  - Are output independent goals met?
    e.g. Performance, Scalability, Security, *Documentation*
Targeting Quality Objectives

- **Functional**
  - Does the program provide expected output for a given input?
    e.g. Correct Output. All features present. Interface design.

- **Nonfunctional**
  - Are output independent goals met?
    e.g. Performance, Scalability, Security, *Documentation*

We'll start this semester by looking at functional goals.
Subtle Terminology

- **Fault / Defect**
  - Flaws in static software (e.g. incorrect code)
Subtle Terminology

- **Fault / Defect**
  - Flaws in static software (e.g. incorrect code)

- **Failure**
  - An observable, incorrect behavior as compared to expected results
Subtle Terminology

- **Fault / Defect**
  - Flaws in static software (e.g. incorrect code)

- **Failure**
  - An observable, incorrect behavior as compared to expected results

- **Error / Infection**
  - Incorrect internal state (not yet observed)
Subtle Terminology

- **Fault / Defect**
  - Flaws in static software (e.g. incorrect code)

- **Failure**
  - An observable, incorrect behavior as compared to expected results

- **Error / Infection**
  - Incorrect internal state (not yet observed)

- **Latent Defect**
  - Unobserved defects in delivered software that testing did not expose
Subtle Terminology

- **Fault / Defect**
  - Flaws in static software (e.g. incorrect code)

- **Failure**
  - An observable, incorrect behavior as compared to expected results

- **Error / Infection**
  - Incorrect internal state (not yet observed)

- **Latent Defect**
  - Unobserved defects in delivered software that testing did not expose

The later a defect is found, the more it costs to fix. Why?
A Simple Example

```c
void toUppercase(char *str) {
    for (int i = 0, e = strlen(str) - 1; i < e; ++i) {
        if (isletter(str[i]) && islower(str[i])) {
            str[i] = str[i] - 32;
        }
    }
    printf(“%s\n”, str);
}
```
A Simple Example

```c
void toUppercase(char *str) {
    for (int i = 0, e = strlen(str) - 1; i < e; ++i) {
        if (isletter(str[i]) && islower(str[i])) {
            str[i] = str[i] - 32;
        }
    }
    printf(“%s\n”, str);
}
```

- What is a fault in this program?
A Simple Example

void toUppercase(char *str) {
    for (int i = 0, e = strlen(str) - 1; i < e; ++i) {
        if (isletter(str[i]) && islower(str[i])) {
            str[i] = str[i] - 32;
        }
    }
    printf("%s\n", str);
}

• What is a fault in this program?
• What is a test case that has a failure?
A Simple Example

```c
void toUppercase(char *str) {
    for (int i = 0, e = strlen(str) - 1; i < e; ++i) {
        if (isletter(str[i]) && islower(str[i])) {
            str[i] = str[i] - 32;
        }
    }
    printf("%s\n", str);
}
```

- What is a fault in this program?
- What is a test case that has a failure?
- What is a test case that does not have a failure?
A Simple Example

void toUppercase(char *str) {
    for (int i = 0, e = strlen(str) - 1; i < e; ++i) {
        if (isletter(str[i]) && islower(str[i])) {
            str[i] = str[i] - 32;
        }
    }
    printf("%s\n", str);
}

- What is a fault in this program?
- What is a test case that has a failure?
- What is a test case that does not have a failure?

What exactly do we mean by test case?
Test Cases

Test cases need

- Input to provide the program
- Expected output or behavior to check for correctness
Test Cases

Test cases need

- Input to provide the program
- Expected output or behavior to check for correctness
Test Cases

Test cases need

- Input to provide the program
- Expected output or behavior to check for correctness

But where does the expected behavior come from?

- An *oracle*
Test Oracles

• In general, a means of deciding whether a test passes or fails (was the behavior expected or not)
Test Oracles

- In general, a means of deciding whether a test *passes* or *fails* (was the behavior expected or not)

- Sometimes very simple
  - How are unit tests evaluated?
Test Oracles

- In general, a means of deciding whether a test passes or fails (was the behavior expected or not)
- Sometimes very simple
  - How are unit tests evaluated? (Test Drivers!)
Test Oracles

- In general, a means of deciding whether a test passes or fails (was the behavior expected or not)
- Sometimes very simple
  - How are unit tests evaluated? (Test Drivers!)
- Sometimes tricky
  - Is result strictly specified? (content, order, timing, ...)
  - Is the program deterministic?
Test Oracles

• In general, a means of deciding whether a test passes or fails (was the behavior expected or not)

• Sometimes very simple
  – How are unit tests evaluated? (Test Drivers!)

• Sometimes tricky
  – Is result strictly specified? (content, order, timing,...)
  – Is the program deterministic?

• Sometimes requires a person
  – Expensive and undesirable
  – “Does this software meet my needs?”
Coverage / Adequacy

Recall: can't look at all possible inputs.
Coverage / Adequacy

Recall: can't look at all possible inputs.

Need to determine if a test suite *covers / is adequate* for our quality objectives.
Coverage / Adequacy

Recall: can't look at all possible inputs.

Need to determine if a test suite \textit{covers / is adequate} for our quality objectives.

- Sufficiently addresses criteria
- Lack of failures provides enough confidence that the software is acceptable
Coverage / Adequacy

Recall: can't look at all possible inputs.

Need to determine if a test suite covers / is adequate for our quality objectives.

- Sufficiently addresses criteria
- Lack of failures provides enough confidence that the software is acceptable

Key Idea:
- Find a finite test suite that is representative of our goals
Approaches

- Test until you run out of time
- Test until you run out of money
Approaches

- Test until you run out of time
- Test until you run out of money
- Identify redundant inputs based on *the specification*
Approaches

- Test until you run out of time
- Test until you run out of money
- Identify redundant inputs based on *the specification*
- Identify redundant inputs based on *program structure*
Approaches

- Test until you run out of time
- Test until you run out of money
- Identify redundant inputs based on the specification
- Identify redundant inputs based on program structure
- Identify poorly tested areas by measuring how well your tests identify potential bugs
Approaches

- Test until you run out of time
- Test until you run out of money
- Identify redundant inputs based on program structure
- Identify redundant inputs based on the specification
- Identify poorly tested areas by measuring how well your tests identify potential bugs

No approach covers everything you want! Need to combine them for a balanced approach toward the desired goals.
Where we will go with testing

In the future, we will look at:

- Different types of testing (Unit, UI, Performance, ...)
- How to measure testing
- How to create new tests automatically
- How to test challenging scenarios (ML? Simulations?)
Next Up...

Revisit the basics of unit testing.