CSE 331

Software Design & Implementation

Topic: Software Tools

💬 **Discussion:** What's a movie or show that you've enjoyed recently?

Reminders

- Before lecture today, we had office hours
- Today's lecture is experimental

Upcoming Deadlines

- HW4 due Thursday (7/13)

Late Days

"No questions asked" late day policy:

- No more than ***one* late day** per assignment.
- No more than **six late days** total during the quarter.

"Questions asked" policy:

- Email us if you need more time
- Potential Downsides:
  - we may not be able to get you feedback quickly
  - you may fall behind on future assignments

Some quick reasoning…

Assertion 1: Students feel motivated to cheat in high-stress environments.
Assertion 2: Many of you find CSE 331 to be a high-stress environment.

=> Many of you feel motivated to cheat

Don't do it!

- academically dishonest
- it won't get you a high grade on an assignment
- it will build an unhealthy reliance and degrade your thinking

Instead come to talk to the course staff. We'll help you!

Last Time…

- Design Principles
- Design in Java
- Style

Today's Agenda

- Software Tools
- Tools for Testing
  - Test-case Ordering
  - Mutation Testing
- Other Tools

Software Tools

What is high quality?

Code is high quality when it is

1. **Correct**
   Everything else is of secondary importance

2. Easy to **change**
   Most work is making changes to existing systems

3. Easy to **understand**
   Needed for 1 & 2 above

How do we ensure correctness?

Best practice: use three techniques (we'll study each)

1. **Tools**
   - type checkers, test runners, etc.
2. **Inspection**
   - think through your code carefully
   - have another person review your code
3. **Testing**
   - usually >50% of the work in building software

technical interviews focus on this (a.k.a. "reasoning")

Together can catch >97% of bugs.

What is a software tool?

A **tool** is something that helps us write high-quality software.

- Forward/backward reasoning
- AFs, RIs, and ADTs

A **software tool** is a piece of software that helps us write high-quality software

- Describes a very large class of things
- We've seen a couple of these
- E.g. Git, IntelliJ, IntelliSense, Java compiler

What is a software tool?

What is a software tool?

How do people build software tools?

1. Identify a problem
2. Understand how developers currently solve it
3. Attempt to automate that process

In order to automate it, we need to define the solution precisely.

Until recently…   

What is a software tool?

Disclaimer: I am not an expert!

If you find this work interesting, talk to the experts on campus

- UW PLSE, https://uwplse.org/
- UW NLP, https://www.cs.washington.edu/research/nlp
- Consider joining research https://www.cs.washington.edu/findingresearch

Tools for Testing

Testing so far…

In practice, to make a good test suite for a function we need

1. A way make test cases **[testing heuristics]**
2. A way to determine if we have enough test cases **[code coverage]**

An algorithm to generate test suites:

```
suite = []
while (not enough test cases) {
     test = ...   // make a new test
     suite.add(test)
}
```

Brainstorm: Testing

How could we automate test case generation?

Test Generation: History

We can make test cases by reusing the input data from clients.

Benefits	Drawbacks

Test Generation: Random

We can make test cases by randomly picking elements from our input space.

Benefits	Drawbacks

Recall: Example

```
suite = []
while (not enough test cases) {
      test = ... // make a test
      suite.add(test)
}
```

```
// returns:  x < 0     => returns -x
//           otherwise => returns x
int abs(int x) {
   if (x < -2) return -x;
   else        return x;
}
```

What **test cases** might we want to consider for our test suite?

```
{…, -4, -3, -2, -1, 0, 1, 2, 3, …}
```

is our entire input space.

Test Generation: Random

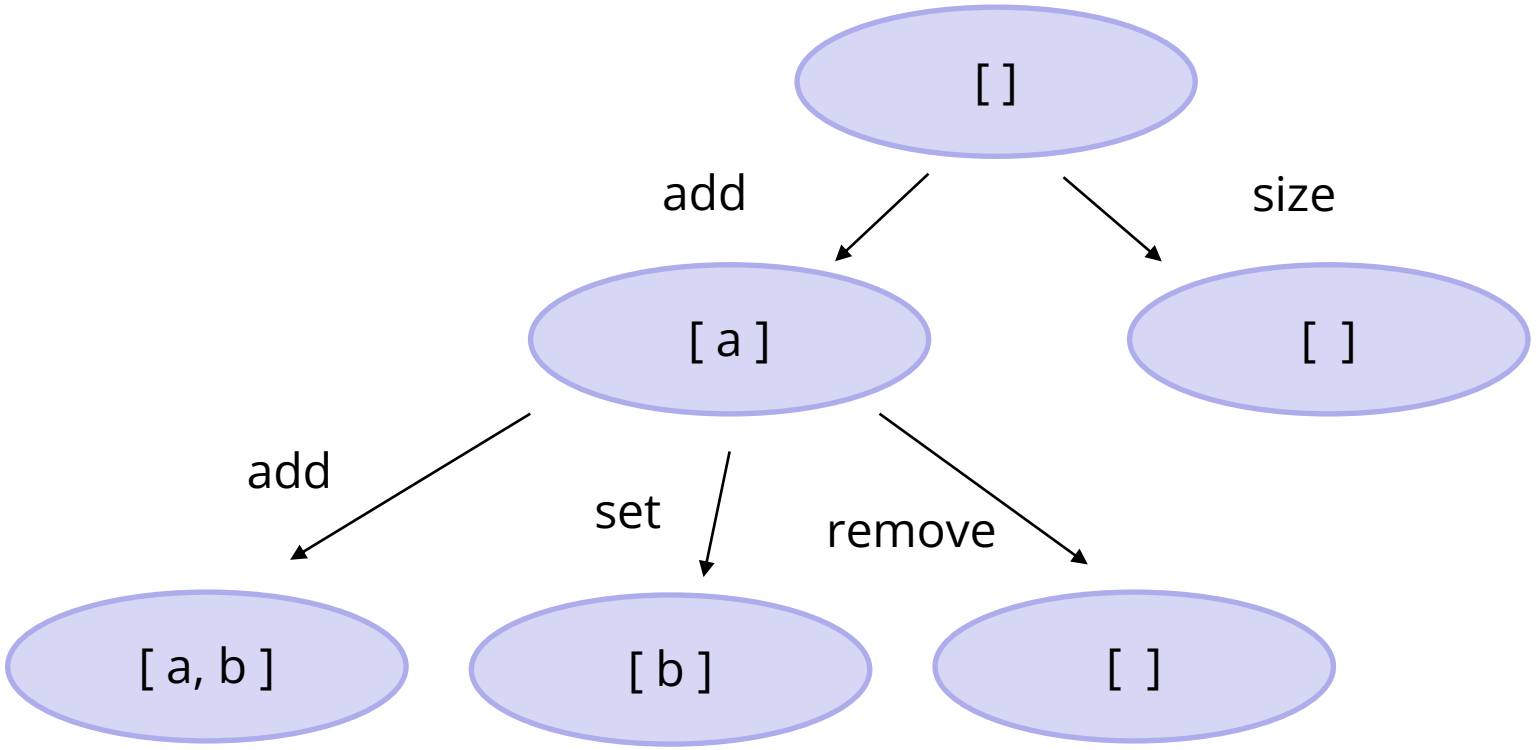
We can make test cases by randomly picking elements from our input space.

Benefits	Drawbacks

Sometimes called fuzzing.

Test Generation: Random Objects

We can make test cases by randomly applying method calls to an object.



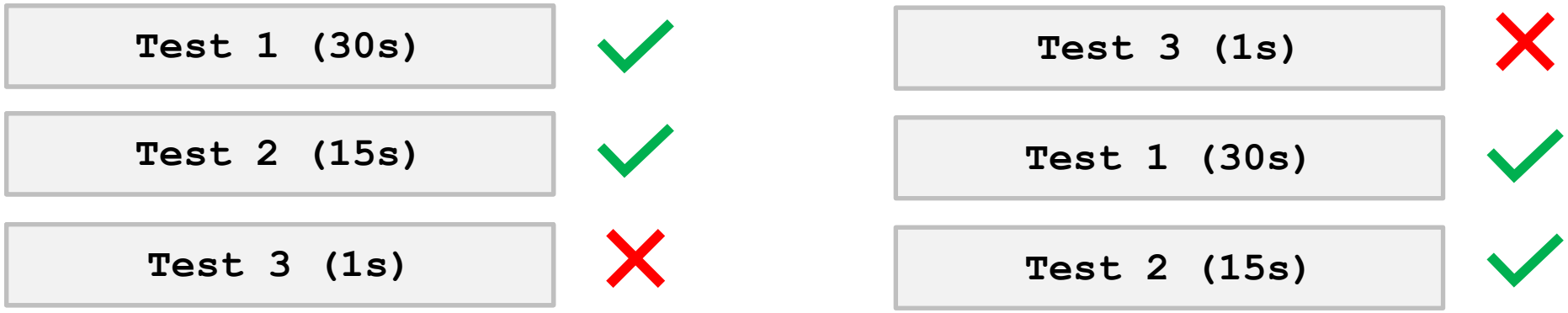
Test Generation: Specifications

We can make test cases by reading the specification.

Benefits	Drawbacks

Test-case Ordering

Does the order that we execute test cases matter?



We usually prefer to prioritize failing test cases.

- Investigate failures, not successes
- Failed test cases tend to fail early

Code Coverage

Naive Attempt: how many lines of code did we run?

```
assert isEven(2)
assert isEven(4)


coverage = 3/5 = 60%
```

```
1  function isEven(x):
2    if (x % 2 == 0):
3        return true
4    else:
5        return false
```

Code Coverage

Naive Attempt: how many lines of code did we run?

```
assert isEven(2)
assert !isEven(3)


coverage = 100%
```

```
1  function isEven(x):
2    if (x % 2 == 0):
3        return true
4    else:
5        return false
```

Code Coverage

Naive Attempt: how many lines of code did we run?

```
isEven(2)
!isEven(3)


coverage = 100%
```

(even though tests do nothing!)

```
1  function isEven(x):
2    if (x % 2 == 0):
3        return true
4    else:
5        return false
```

Mutation Testing

Better Attempt: let's introduce bugs into our code by making "mutant" programs

```
1  function isEven(x):
2    if (x % 2 == 0):
3        return true
4    else:
5        return false
```

Mutant #1 →

```
function isEven(x):
    if (x % 2 != 0):
        return true
    else:
        return false
```

Mutant #2 →

```
function isEven(x):
    if (x % 2 == 1):
        return true
    else:
        return false
```

Note: Need to define allowed mutations

Mutation Testing

Better Attempt: let's introduce single-line bugs into our code (i.e. mutants)

```
assert isEven(2)
assert isEven(3)


mutants score = 100%
```

Mutant #1 →

```
function isEven(x):
    if (x % 2 != 0):
        return true
    else:
        return false
```

Mutant #2 →

```
function isEven(x):
    if (x % 2 == 1):
        return true
    else:
        return false
```

Mutation Testing so far…

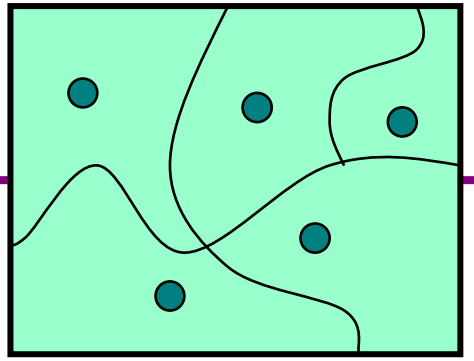
In practice, to make a good test suite for a function we need

1. A way make test cases
2. A way to determine if we have enough test cases **[mutation score]**

An algorithm to generate test suites:

```
suite = []
while (undetected mutants) {
    mutant = ...  // introduce a bug that breaks our tests
    test = ...    // make a test that catches that bug
    suite.add(test)
}
```

Mutation Testing



A subdomain is *revealing* for error *E* if either:

- *every* input in that subdomain triggers error E, *or*
- *no* input in that subdomain triggers error E

Each test case produced with mutation testing reveals some bug!

So why don't people use it in practice?

- Need to define the single-line mutations allowed

Other Tools

Correctness:

- Fault localization
- Program verification
- Program analysis
  - Static vs. dynamic
- Program synthesis

Changeability:

- Code generation

Understandability:

- Linters

Tools for Testing

Other Tools: Fault Localization

Given your software and a failing test identify where the bug is likely to be.

- Could be approximate (e.g. this region)
- Could be multiple answers

Other Tools: Automated Program Repair

Given your software and a failing test suite, identify a patch that fixes the code.

Other Tools: Program Verification

Given your software and formal specification, prove that code is correct.

- Model checking
- Deductive verification

Other Tools: Program Analysis

Given your software, identify if it has some property.

- Static analysis
  - Data-flow analysis for taint checking
- Dynamic analysis
  - Program slicing

Other Tools: Program Synthesis

Given a formal specification, identify a program that satisfies that implementation.

Other Tools

Changeability:

- Code generation
- Feedback

Understandability:

- Linters

Note: this list is actually very long!

Before next class…

1. Ask us questions about HW4!
   - Lots of good discussion on Ed

2. Section tomorrow will focus on HW5 preparation.