

Software Engineering (Part 3)

Copyright © 2025 by
Robert M. Dondero, Ph.D.
Princeton University

Objectives

- We will cover these software engineering topics:

Stages of SW dev

How to order the stages

- Requirements analysis
- Design
- Implementation
- Debugging
- Testing
- Evaluation
- Maintenance
- Process models

Objectives

Software Engineering lecture slide decks:

Part 1	Requirements analysis Design (general)
Part 2	Design (object-oriented) Implementation
Part 3	Debugging Testing Evaluation
Part 4	Maintenance Process models

You've implemented your system in code.
What's next?

Agenda

- Requirements analysis
- Design
- Implementation
- **Debugging**
- Testing
- Evaluation
- Maintenance
- Process models

Debugging

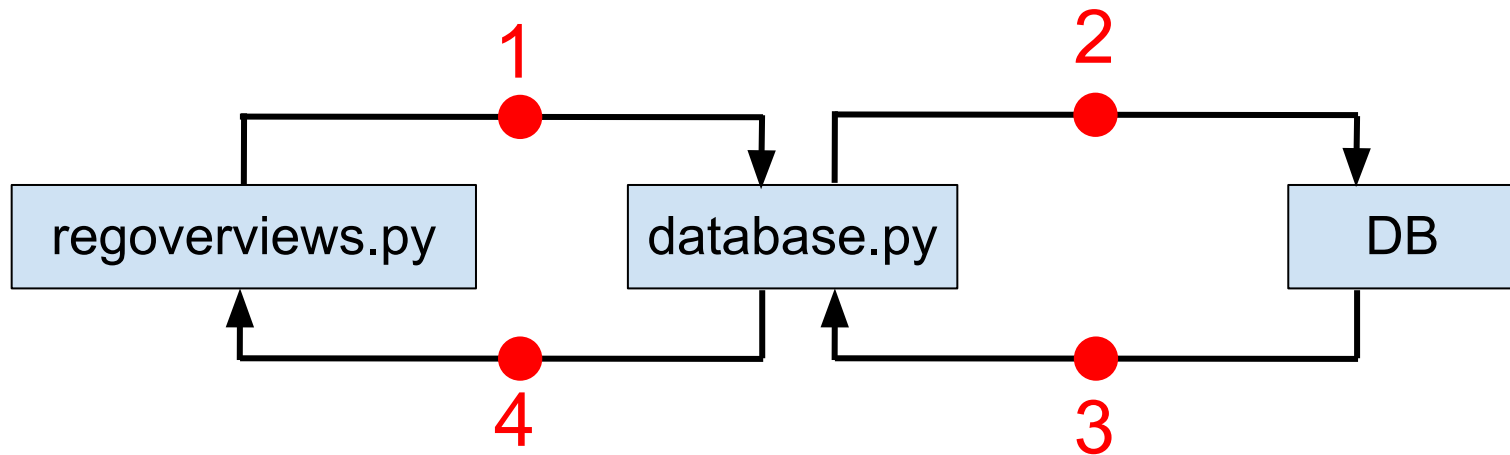
- *Debugging*
 - How can I fix the system?

Debugging

- Debugging techniques (from COS 217)
 - Divide and conquer

Debugging

Asgt 1:



- (1) Print the query data structure
- (2) Print the SQL statement
- (3) Print the populated cursor
- (4) Print the list of classes

Debugging

- Debugging techniques (from COS 217)
 - Add more internal tests
 - Focus on recent changes
 - Display output

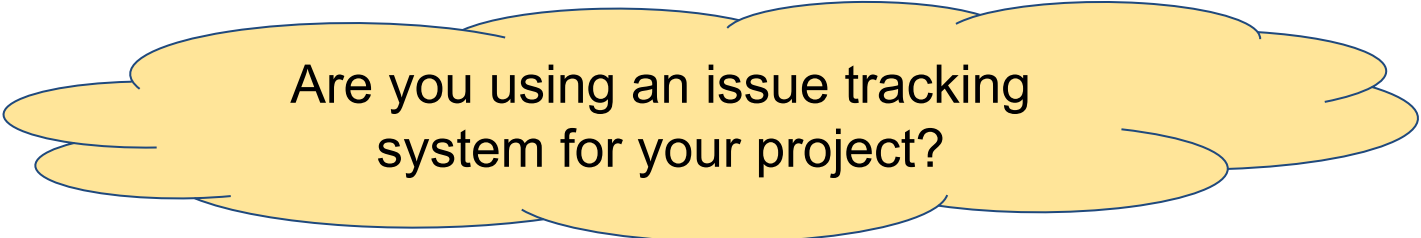
Debugging

- Debugging techniques (from COS 217)
 - Use a debugger

Language	Debugger	Reference
Assem lang	gdb	COS 217
C	gdb	COS 217
Python	pdb	Appendix of <i>The Python Language (Part 5)</i>
Java	jdb	https://docs.oracle.com/javase/7/docs/technote/s/tools/windows/jdb.html
JavaScript	Chrome Firefox ...	https://www.w3schools.com/js/js_debugging.asp
JavaScript	Node.js	https://nodejs.org/api/debugger.html

Debugging

- Debugging techniques (not from COS 217)
 - Use an **issue tracking system**
 - **Examples:** Issues (GitHub), Bugzilla (open source), Jira (Atlassian), Trello (Atlassian), Trac (open source), ...
 - See https://en.wikipedia.org/wiki/Comparison_of_issue_tracking_systems



Are you using an issue tracking system for your project?

You're reasonably sure that your code is bug-free. What's next?

Agenda

- Requirements analysis
- Design
- Implementation
- Debugging
- **Testing**
- Evaluation
- Maintenance
- Process models

Testing

- **Debugging**: How can I **fix** the system?
- *Testing*: How can I **break** the system?

Testing

- Testing taxonomy
 - Internal testing
 - External testing
 - White box
 - Black box
 - General strategies

Testing: Internal

- *Internal testing*
 - Designing your code to test itself
 - Done by *programmers*

Testing: Internal

- Internal testing techniques
 - Check for function/method failures
 - Validate parameters
 - Check invariants
 - Leave testing code intact!!!

Testing: Internal

C: `assert` macro

```
assert(count >= 0);
```

Essentially same as:

```
if (count < 0)
{
    fprintf(stderr,
        "assertion failed: (count >= 0),");
    fprintf(stderr,
        "function XXX, file YY, line ZZ.");
    exit(134);
}
```

Asserts are **enabled** by default; to **disable** asserts:

```
gcc -D NDEBUG somefile.c
```

Testing: Internal

Python: `assert` statement

```
assert count >= 0, 'count is < 0'
```

Essentially same as:

```
if count < 0:  
    raise AssertionError('count is < 0')
```

Asserts are **enabled** by default; to **disable** asserts:

```
python -O somefile.py
```

Testing: Internal

Java: `assert` statement (since JDK 1.4)

```
assert count >= 0 : "count is < 0";
```

Essentially same as:

```
if (count < 0)
    throw new AssertionError("count is < 0");
```

Asserts are **disabled** by default; to **enable** asserts:

```
java -ea SomeFile.java
```

Testing: Internal

JavaScript (browsers):

`console.assert` function

```
console.assert(count >= 0, 'count is < 0');
```

Essentially same as:

```
if (count < 0)  
    console.error('count is < 0');
```

Cannot be disabled???

Testing: Internal

JavaScript (Node.js): `assert` function

```
const assert = require('assert');  
...  
assert(count >= 0);
```

Essentially same as:

```
if (count < 0)  
  throw new Error(  
    'The expression evaluated to a falsy value');
```

Cannot be disabled!

Testing: Internal

- Assert controversy: enable or disable asserts in production code?

Testing: External

- *External testing*
 - Designing code or data to test your code

Testing: External: White Box

- ***White box* external testing**
 - External testing with knowledge of structure of tested code
 - Done by **programmers**

Testing: External: White Box

- White box external testing techniques
 - *Statement (coverage) testing*
 - Testing to make sure each **statement** is executed at least once
 - *Path testing*
 - Testing to make sure each **logical path** is followed at least once

Testing: External: White Box

- White box external testing techniques
 - ***Boundary (corner case) testing***
 - Testing with input values at, just below, and just above limits of input domain
 - Testing with input values causing output values to be at, just below, and just above the limits of the output domain

Glossary of Computerized System and Software Development Terminology

Testing: External: Black Box

- ***Black box* external testing**
 - External testing without knowledge of structure of tested code
 - Done by *quality assurance (QA) engineers*

Testing: External: Black Box

- Black box external testing techniques
 - *Use case testing*
 - Testing driven by use cases developed during design
 - *Stress testing*
 - Testing with a large quantity of data
 - Testing with a large variety of (random?) data

Testing: General Strategies

- **General testing strategies**
 - Automate the testing
 - To test your **programs**: create **scripts**
 - To test your **modules**: create software **clients**
 - Compare implementations when possible
 - Tools for test automation
 - (Next lecture)

Testing

Kinds of automated testing:

	Unit Testing	System/Integration Testing
What	Test modules (classes, functions, methods)	Test programs
When	Often compose tests for module X before composing X	Typically compose tests for program X after composing X
Who	Often performed by a single programmer , or a small group	Often performed by a QA organization

Testing: General Strategies

- General testing strategies (cont.)
 - Test incrementally
 - Use scaffolds and stubs
 - Do *regression testing*
 - Let debugging drive testing
 - Reactive mode
 - Proactive mode: do *fault injection*

Testing: Summary

- Testing taxonomy
 - Internal testing
 - External testing
 - White box
 - Black box
 - General strategies

You've tested your code to make sure it meets your expectations. What's next?

Agenda

- Requirements analysis
- Design
- Implementation
- Debugging
- Testing
- **Evaluation**
- Maintenance
- Process models

Evaluation

- **Testing**

- Does the system meet **your (the programmer's)** expectations?

- ***Evaluation***


- Does the system meet **the users'** expectations?
- Does the system fulfill the needs of its users?

Evaluation

- Kinds of evaluation
 - By users
 - Actually, by software engineers in collaboration with users
 - By evaluation experts

Evaluation: Users

- Questionnaires
- **Interviews**
- Focus groups
- Direct observation



Recall
requirements
gathering
techniques

Evaluation: Users

1. Recruit a set of users.
2. If necessary, compose a short written intro.
3. Compose a task sequence (maybe abstracted from use cases developed during design).
4. For each user:
 - 4.1. If necessary, give the user the short intro, ask the user to read it, and confirm that the user understands it.
 - 4.2. Give the user the task sequence.
 - 4.3. For each task:
 - 4.3.1. Ask the user to read the task and confirm that the user understands it.
 - 4.3.2. Ask the user to use your system to perform the task.
 - 4.3.3. Ask (force!!!) the user to talk aloud while performing the task.
5. Take copious notes.
6. Audio/video record?
7. Repeat for each kind of user.

Evaluation: Experts



Jakob
Nielsen

Evaluation: Experts

- *Heuristic Evaluation*
 - From Jakob Nielsen
 - For evaluating the **whole** system **generally**
 - Using these 10 heuristics...

Evaluation: Experts

- *Heuristic Evaluation*

- **(1) Visibility of system status**

- **The system should always keep users informed** about what is going on, through appropriate feedback within reasonable time.

Evaluation: Experts

- *Heuristic Evaluation*

- **(2) Match between system and the real world**
 - **The system should speak the user's language**, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

Evaluation: Experts

- *Heuristic Evaluation*

- **(3) User control and freedom**

- **Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.**

Evaluation: Experts

- *Heuristic Evaluation*

- **(4) Consistency and standards**

- Users should not have to wonder whether different words, situations, or actions mean the same thing. **Follow platform conventions.**

Evaluation: Experts

- *Heuristic Evaluation*

- **(5) Error prevention**

- **Even better than good error messages is a careful design which prevents a problem from occurring** in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

Evaluation: Experts

- *Heuristic Evaluation*

- **(6) Recognition rather than recall**

- Minimize the user's memory load by **making objects, actions, and options visible**. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

Evaluation: Experts

- *Heuristic Evaluation*

- **(7) Flexibility and efficiency of use**

- Accelerators—unseen by the novice user—may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. **Allow users to tailor frequent actions.**

Evaluation: Experts

- *Heuristic Evaluation*

- **(8) Aesthetic and minimalist design**

- **Dialogues should not contain information which is irrelevant** or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

Evaluation: Experts

- *Heuristic Evaluation*

- **(9) Help users recognize, diagnose, and recover from errors**
 - **Error messages should be expressed in plain language** (no codes), precisely indicate the problem, and constructively suggest a solution.

Evaluation: Experts

- *Heuristic Evaluation*

- **(10) Help and documentation**

- Even though it is better if the system can be used without documentation, it may be necessary to **provide help and documentation**. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Evaluation: Experts

- For more info on heuristic evaluation:
 - Wikipedia article:
https://en.wikipedia.org/wiki/Heuristic_evaluation
 - Helen Sharp, Jenny Preece, Yvonne Rogers. *Interaction Design: Beyond Human-Computer Interaction*.
 - Nielsen, Jakob. *Usability Engineering*.

Evaluation: Experts

- **Cognitive Walkthrough**
 - From Cathleen Wharton, Jakob Nielsen
 - For evaluating **part** of the system in **detail**

Repeatedly:

Will the correct action be sufficiently evident to the user?

Will the user know what to do to achieve the task?

Will the user notice that the correct action is available?

Can users see the button or menu item that they should use for the next action?

Will the user associate and interpret the response from the action correctly?

Will users know from the feedback that they have made the correct or incorrect choice of action?

So the system is finished. Or is it?

Continued in
Software Engineering (Part 4)...