Debugging

BBM 101 - Introduction to Programming I

Hacettepe University
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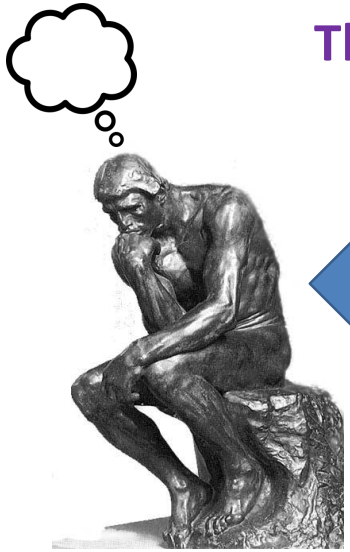
Fuat Akal, Aykut Erdem, Erkut Erdem

Slides based on material prepared by Ruth Anderson, Michael Ernst and Bill Howe in the course CSE 140 University of Washington

The Problem



Not the same!

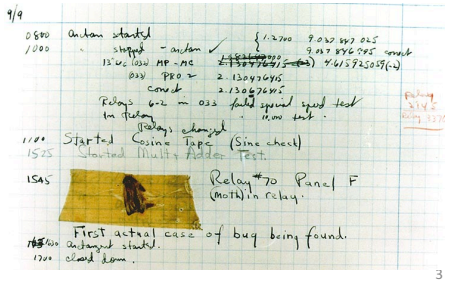
There is a bug!

What you want your program to do

What your program does

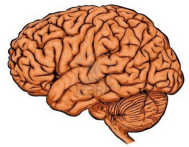
What is Debugging?

- Grace Hopper was one of U.S.'s first programmers.
- She found a moth in the Mark I computer, which was causing errors, and called it a computer "bug"
- Thus, the word debugging is coined ☺



Debugging Tools

- Python error message
- **`assert`**
- **`print`**
- Python interpreter
- Python Tutor (http://pythontutor.com)
- Python debugger
- Best tool:



Two Key Ideas

1. The scientific method
2. Divide and conquer

If you master those, you will find debugging easy, and possibly enjoyable ;-)

The Scientific Method

1. Create a hypothesis
2. Design an experiment to test that hypothesis
   - Ensure that it yields insight
3. Understand the result of your experiment
   - If you don't understand, then possibly suspend your main line of work to understand that

Tips:

- Be systematic
  - Never do anything if you don't have a reason
  - Don't just flail
    - Random guessing is likely to dig you into a deeper hole
- Don't make assumptions (verify them)

Example Experiments

1. An alternate implementation of a function
   - Run all your test cases afterward
2. A new, simpler test case
   - Examples: smaller input, or test a function in isolation
   - Can help you understand the reason for a failure

Your Scientific Notebook

Record everything you do

- Specific inputs and outputs (both expected and actual)
- Specific versions of the program
  - If you get stuck, you can return to something that works
  - You can write multiple implementations of a function
- What you have already tried
- What you are in the middle of doing now
  - This may look like a stack!
- What you are sure of, and why

Your notebook also helps if you need to get help or reproduce your results.

Read the Error Message

```
Traceback (most recent call last):
  File "nx_error.py", line 41, in <module>
    print(friends_of_friends(rj, myval))
  File "nx_error.py", line 30, in friends_of_friends
    f = friends(graph, user)
  File "nx_error.py", line 25, in friends
    return set(graph.neighbors(user))#
  File "/Library/Frameworks/…/graph.py", line 978, in neighbors
    return list(self.adj[n])
TypeError: unhashable type: 'list'
```

First function that was called (**<module>** means the interpreter)

Second function that was called

Call stack or traceback

Last function that was called (this one suffered an error)

The error message: daunting but useful.
You need to understand:

- the literal meaning of the error
- the underlying problems certain errors tend to suggest

List of all exceptions (errors):
http://docs.python.org/3/library/exceptions.html#bltin-exceptions
Two other resources, with more details about a few of the errors:
http://inventwithpython.com/appendixd.html
http://www.cs.arizona.edu/people/mccann/errors-python

Common Error Types

- **AssertionError**
  - Raised when an assert statement fails.
- **IndexError**
  - Raised when a sequence subscript is out of range.
- **KeyError**
  - Raised when a mapping (dictionary) key is not found in the set of existing keys.
- **KeyboardInterrupt**
  - Raised when the user hits the interrupt key (normally Control-C or Delete).
- **NameError**
  - Raised when a local or global name is not found.
- **SyntaxError**
  - Raised when the parser encounters a syntax error.
- **IndentationError**
  - Base class for syntax errors related to incorrect indentation.
- **TypeError**
  - Raised when an operation or function is applied to an object of inappropriate type.

Divide and Conquer

- Where is the defect (or "bug")?
- Your goal is to find the one place that it is
- Finding a defect is often harder than fixing it

- Initially, the defect might be anywhere in your program
  - It is impractical to find it if you have to look everywhere
- Idea: bit by bit reduce the scope of your search
- Eventually, the defect is localized to a few lines or one line
  - Then you can understand and fix it

- 4 ways to divide and conquer:
  - In the program code
  - In test cases
  - During the program execution
  - During the development history

Divide and Conquer in the Program Code

- Localize the defect to part of the program
  - e.g., one function, or one part of a function
- Code that isn't executed cannot contain the defect

3 approaches:

- Test one function at a time
- Add assertions or print statements
  - The defect is executed before the failing assertion (and maybe after a succeeding assertion)
- Split complex expressions into simpler ones

  Example: Failure in

  ```
  result = set({graph.neighbors(user)})
  ```

  Change it to

  ```
  nbors = graph.neighbors(user)
  nbors_set = {nbors}
  result = set(nbors_set)
  ```

  The error occurs on the "nbors_set = {nbors}" line

Divide and Conquer in Test Cases

- Your program fails when run on some large input
  - It's hard to comprehend the error message
  - The log of print statement output is overwhelming
- Try a smaller input
  - Choose an input with some but not all characteristics of the large input
  - Example: duplicates, zeroes in data, …

Divide and Conquer in Execution Time via Print (or "logging") Statements

- A sequence of `print` statements is a record of the execution of your program
- The `print` statements let you see and search multiple moments in time
- Print statements are a useful technique, in moderation
- Be disciplined
  - Too much output is overwhelming rather than informative
  - Remember the scientific method: have a reason (a hypothesis to be tested) for each print statement
  - Don't *only* use print statements

Divide and Conquer in Development History

- The code used to work (for some test case)
- The code now fails
- The defect is related to some line you changed
- This is useful only if you kept a version of the code that worked (use good names!)
- This is most useful if you have made few changes
- Moral: test often!
  - Fewer lines to compare
  - You remember what you were thinking/doing recently

A Metaphor About Debugging

If your code doesn't work as expected, then by definition you don't understand what is going on.

- You're lost in the woods.
- You're behind enemy lines.
- All bets are off.
- Don't trust anyone or anything.

Don't press on into unexplored territory -- go back the way you came!
(and leave breadcrumbs!)

You're trying to "advance the front lines," not "trailblaze"

Time-Saving Trick: Make Sure You are Debugging the Right Problem

- The game is to go from "working to working"
- When something doesn't work, STOP!
  - It's wild out there!
- FIRST: Go back to the last situation that worked properly.
  - Rollback your recent changes and verify that everything still works as expected.
  - Don't make assumptions – by definition, you don't understand the code when something goes wrong, so you can't trust your assumptions.
  - You may find that even what previously worked now doesn't
  - Perhaps you forgot to consider some "innocent" or unintentional change, and now even tested code is broken

A Bad Timeline

- A works, so celebrate a little
- Now try B
- B doesn't work
- Change B and try again
- Change B and try again
- Change B and try again

…

A Better Timeline

- A works, so celebrate a little
- Now try B
- B doesn't work
- *Rollback to A*
- Does A still work?
  - Yes: Find A' that is somewhere between A and B
  - No: You have *unintentionally changed something else*, and there's no point futzing with B at all!

These "innocent" and unnoticed changes happen more than you would think!
- You add a comment, and the indentation changes.
- You add a print statement, and a function is evaluated twice.
- You move a file, and the wrong one is being read
- You are on a different computer, and the library is a different version

Once You are on Solid Ground You can Set Out Again

- Once you have something that works and something that doesn't work, it is only a matter of time
- You just need to incrementally change the working code into the non-working code, and the problem will reveal itself.
- Variation: Perhaps your code works with one input, but fails with another. Incrementally change the good input into the bad input to expose the problem.

Simple Debugging Tools

`print`

- shows what is happening whether there is a problem or not
- does not stop execution

`assert`

- Raises an exception if some condition is not met
- Does nothing if everything works
- Example: `assert len(rj.edges()) == 16`
- Use this liberally! Not just for debugging!