Making Programs Fail

Andreas Zeller

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Two Views of Testing

- Testing means to execute a program with the intent to make it fail.
- Testing for validation:
  Finding *unknown* failures (classical view)
- Testing for debugging:
  Finding a *specific* failure (our focus)

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Tests in Debugging

- Write a test to *reproduce* the problem
- Write a test to *simplify* the problem
- Run a test to *observe* the run
- Run a test to *validate a fix*
- Re-run tests to protect against *regression*

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Automated Tests

- Allow for *reuse* of tests
- Allow tests that are difficult to carry out manually
- Make tests repeatable
- Increase confidence in software

Automated Tests

- Allow to isolate and simplify
  - *failure-inducing input*
  - *failure-inducing code changes*
  - *failure-inducing thread schedules*
  - *failure-inducing program state*
- More on this in the weeks to come

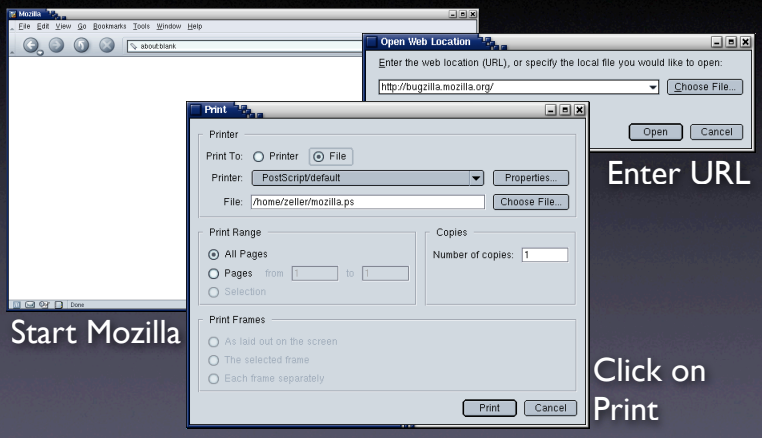
Mozilla Bug #24735

Ok the following operations cause mozilla to crash consistently on my machine

-> Start mozilla
-> Go to bu
-> Select s
-> Print to file setting the bottom and right margins to .50
(I use the file /var/tmp/netscape.ps)
-> Once it's done printing do the exact same thing again on the same file (/var/tmp/netscape.ps)
-> This causes the browser to crash with a segfault

How do we automate this?

Simulating Interaction



Start Mozilla

Enter URL

Click on Print

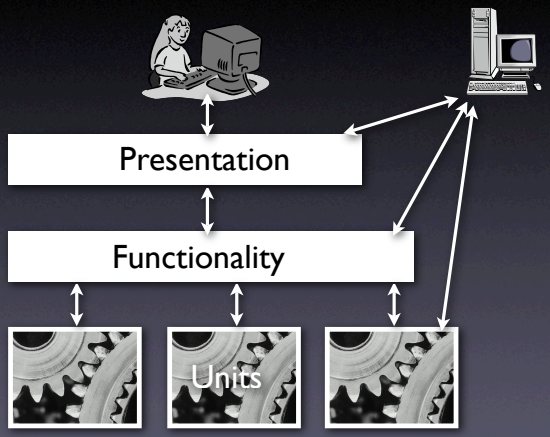
Challenges

- *Synchronization*: How do we know a window has popped up such that we can click into it?
- *Abstraction*: How do we know it's the right window?
- *Portability*: What happens on a display with different resolution or window placement?

Interaction Layers

- The *presentation layer* handles interaction with the user (generally: the environment)
- The *functionality* layer encapsulates the functionality (independent from a specific presentation)
- The *unit layer* splits functionality across cooperating units

Control Layers



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Assessing Layers

- Ease of execution. How easy is it to get control over program execution?
- Ease of interaction. How easy is it to interact with the program?
- Ease of result assessment. How can we check results against expectations?
- Lifetime of test case. How robust is my test when it comes to program changes?

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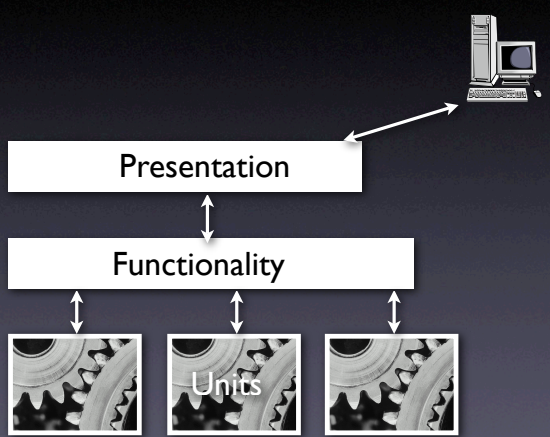
Presentation Layer



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Presentation Layer

- Low-level: expressing interaction by means of mouse and keyboard events
  - Also applicable at the system level
- High-level: expressing interaction using graphical controls

Low Level Interaction

```
# 1. Launch mozilla and wait for 2 seconds
exec mozilla &
send_xevents wait 2000

# 2. Open URL dialog (Shift+Control+L)
send_xevents keydn Control_L
send_xevents keydn Shift_L
send_xevents key L
send_xevents keyup Shift_L
send_xevents keyup Control_L
send_xevents wait 500

# 3. Load bugzilla.mozilla.org and wait for 5 seconds
send_xevents @400,100
send_xevents type {http://bugzilla.mozilla.org}
send_xevents key Return
send_xevents wait 5000
```


Low Level Interaction

- Scripts can easily be *recorded*
- Scripts are *write-only*
  (= impossible to maintain)
- Scripts are *fragile*
  (= must be remade after trivial changes)

System Level Interaction

```
# Power on the machine and wait for 5s
power <= true; wait for 5000;

# Click mouse button 1
m_b1 <= true; wait for 300; m_b1 <= false;

# Click the CDROM change button
cdctrl'shortcut_out_add("/cdrom%change/...");
```

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System Level Interaction

- Complete control over machine
- Good for testing and debugging system properties
- Difficult to use for application programs

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Higher Level Interaction

```
-- 1. Activate mozilla
tell application "mozilla" to activate

-- 2. Open URL dialog via menu
tell application "System Events" to ¬
  tell process "mozilla" to ¬
    tell menu bar 1 to ¬
      tell menu bar item "File" to ¬
        click menu item "Open Web Location"

-- 3. Load bugzilla.mozilla.org and wait for 5 seconds
tell window "Open Web Location"
  tell sheet 1 to ¬
    set value of text field 1 to "http://bugzilla.mozilla.org/"
  click button 1
end tell
delay 5
```

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Higher Level Interaction

- Scripts reference GUI elements by *name* and *numbers* (rather than coordinates)
- Much more robust against size and position changes
- But still fragile against layout changes and renamings

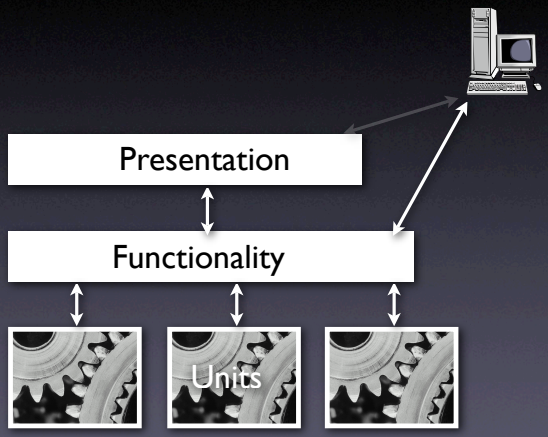
Dealing with Output

- We must be able to detect *output*
  - for *synchronization* ("is the dialog there?")
  - for *assessment of results* ("was the test successful?")
- Issue at entire presentation layer (low level, system level, and high level interface)

Presentation Layer

- Automation is *always feasible*
- Scripts are more or less *fragile*
- Dealing with output is greatest weakness

Functionality Layer



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Design for Automation

- Each application comes with an API for a scripting language

Check state of application

```
tell application "Safari"
  activate
  if not (exists document 1)
    make new document at the beginning of documents
  end if
  set the URL of the front document ¬
    to "http://bugzilla.mozilla.org/"
  delay 5
end tell
```

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Windows Scripting

- Most operating systems provide their own scripting language

```
' Load document
Set IE = CreateObject("InternetExplorer.Application")
IE.navigate "http://bugzilla.mozilla.org/"
IE.visible=1

' Wait until the page is loaded
While IE.Busy
    WScript.Sleep 100
Wend
```

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Emacs Scripting

- Some applications are built around a script interpreter

```
(defun ispell-toggle ()
  "Toggle ispell dictionary between english and german"
  (interactive)
  (cond ((equal ispell-local-dictionary nil)
         (ispell-change-dictionary "american"))
        ((equal ispell-local-dictionary "deutsch8")
         (ispell-change-dictionary "american"))
        (t
         (ispell-change-dictionary "deutsch8")))
  (ispell-init-process)
  (message (concat "Using " ispell-local-dictionary
                   "ispell dictionary")))
```

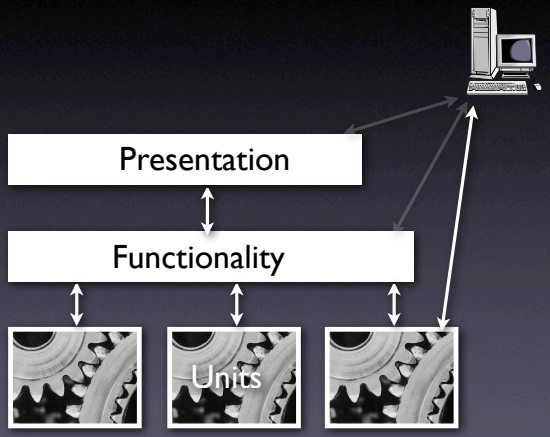

Scripting Languages

- OS-specific languages (MacOS, Windows)
- Perl, Python, Tcl
- Lisp, Scheme, Guile
- Command-line languages (Unix shell)
- Component languages (.NET, Corba)
- … or roll your own (but beware!)

Functionality Layer

- Results can be easily assessed
- Scripts are robust against changes (as long as automation interface remains stable)
- Requires clear separation between presentation and functionality

Unit Layer



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Unit Tests

- Directly access units (= classes, modules, components…) at their programming interfaces
- Encapsulate a set of tests as a single syntactical unit
- Available for all programming languages (JUNIT for Java, CPPUNIT for C++, etc.)

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Running a Test

A test case…

1. *sets up an environment for the test*
2. *tests* the unit
3. *tears down* the environment again.

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Testing a URL Class

http://www.askigor.org/status.php?id=sample

Protocol Host Path Query


```
import junit.framework.Test;
import junit.framework.TestCase;
import junit.framework.TestSuite;

public class URLTest extends TestCase {
    private URL askigor_url;

    // Create new test
    public URLTest(String name) { super(name); }

    // Assign a name to this test case
    public String toString() { return getName(); }

    // Setup environment
    protected void setUp() {
        askigor_url = new URL("http://www.askigor.org/" +
                              "status.php?id=sample"); }
    // Release environment
    protected void tearDown() { askigor_url = null;}
```

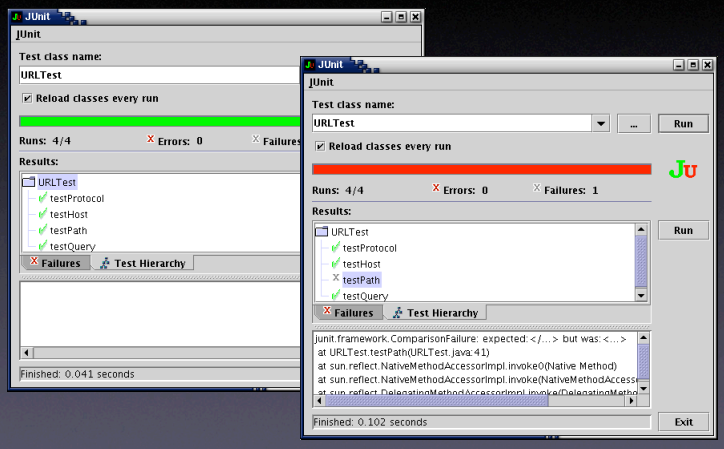


```
    // Test for protocol (http, ftp, etc.)
    public void testProtocol() {
      assertEquals(askigor_url.getProtocol(), "http");
    }

    // Test for host
    public void testHost() {
      int noPort = -1;
      assertEquals(askigor_url.getHost(), "www.askigor.org");
      assertEquals(askigor_url.getPort(), noPort);
    }

    // Test for path
    public void testPath() {
      assertEquals(askigor_url.getPath(), "/status.php");
    }

    // Test for query part
    public void testQuery() {
      assertEquals(askigor_url.getQuery(), "id=sample");
    }
```

The test case can be used as a *specification!*

```
    // Set up a suite of tests
    public static Test suite() {
        TestSuite suite = new TestSuite(URLTest.class);
        return suite;
    }

    // Main method: Invokes GUI
    public static void main(String args[]) {
        String[] testCaseName =
            { URLTest.class.getName() };
        // junit.textui.TestRunner.main(testCaseName);
        junit.swingui.TestRunner.main(testCaseName);
        // junit.awtui.TestRunner.main(testCaseName);
    }
}
```


JUnit



PyUnit

- Unit testing framework for Python
- Simple variant: just overload runTest()

```
import unittest

class DefaultWidgetSizeTestCase(unittest.TestCase):
    def runTest(self):
        widget = Widget("The widget")
        assert widget.size() == (50,50), \
               'incorrect default size'
```

PyUnit Fixtures

```
class WidgetTestCase(unittest.TestCase):
    def setUp(self):
        self.widget = Widget("The widget")
    def tearDown(self):
        self.widget.dispose()
        self.widget = None
    def testDefaultSize(self):
        assert self.widget.size() == (50,50), \
             'incorrect default size'
    def testResize(self):
        self.widget.resize(100,150)
        assert self.widget.size() == (100,150), \
            'wrong size after resize'
```

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Running PyUnit tests

```
if __name__ == "__main__":
    unittest.main()
```

```
$ python unittest.py widgettests.WidgetTestSuite
```

http://pyunit.sourceforge.net/pyunit.html

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Isolating Units

- How do we deal with classes that depend on others?

```
void print_to_file(string filename)
{
    if (path_exists(filename)) {
        // FILENAME exists; ask user to confirm overwrite
        bool confirmed = confirm_loss(filename);
        if (!confirmed)
            return;
    }
    // Proceed printing to FILENAME...
}
```

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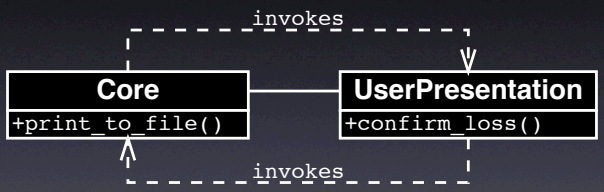
Circular Dependency



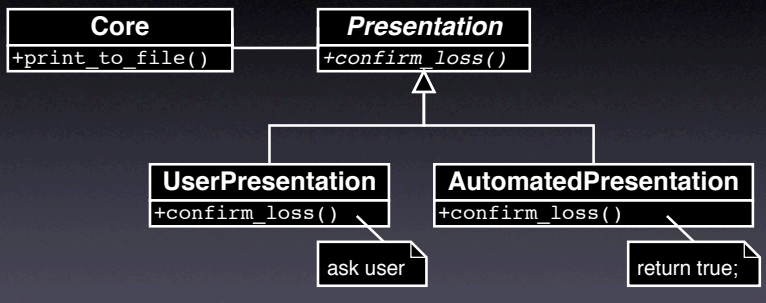
Both units depend on each other!

Broken Dependency

```
void print_to_file(string filename,
                   Presentation *presentation)
{
    if (path_exists(filename))
    {
        // FILENAME exists;
        // ask user to confirm overwrite
        bool confirmed =
            presentation->confirm_loss(filename);
        if (!confirmed)
            return;
    }

    // Proceed printing to FILENAME
    ...
}
```


Revised Dependency



Depend on abstraction rather than details!

Dependency Inversion

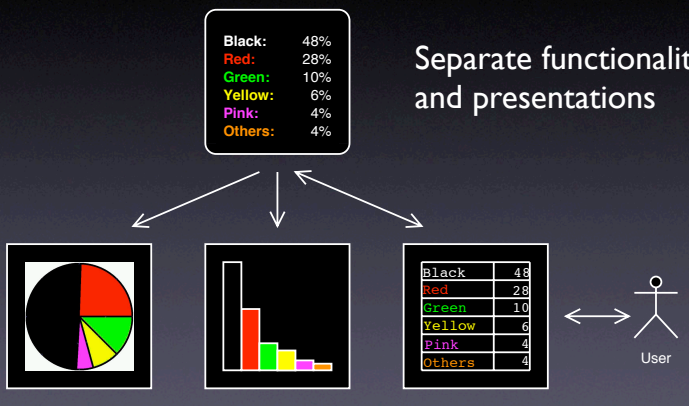
To break the dependency from A to B,

1. Introduce an abstract superclass B'
2. Set up A such that it depends on B' (rather than B)
3. Introduce alternate subclasses of B' that can be used with A

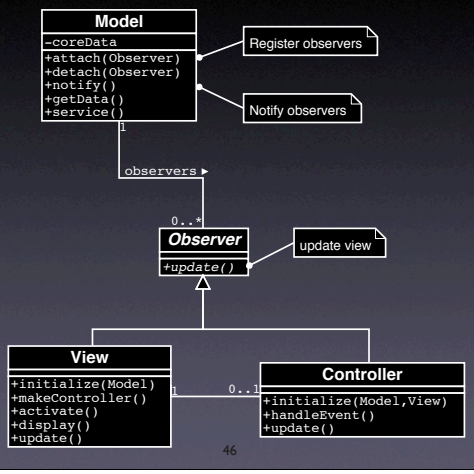
Design for Debugging

- Basic idea: decompose the system such that dependencies are minimized
- Each component depends on a minimum of other components for testing (and debugging)

Model-View-Controller



The MVC Pattern



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General Design Rules

- High cohesion. Those units that operate on common data should be grouped together.
- Low coupling. Units that do not share common data should exchange as little information as possible.

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Prevent Problems

Specify	Test early	Test first
Test often	Test enough	Have reviews
Check the code	Verify	Assert

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Concepts

- To test for debugging, one must…
  - create a test to reproduce the problem
  - run the test several times during debugging, and
  - run the test before new releases to prevent regression
- Automate as much as possible

Concepts (2)

- To test at the presentation layer, simulate human interaction
- To test at the functionality layer, use an automation interface
- To test units, use the unit API to control it and assess its results

Concepts (3)

- To isolate a unit, break dependencies using the dependency inversion principle
- To design for debugging, reduce the amount of dependencies
- A variety of techniques is available to prevent errors and problems

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