Program testing can be used to show the presence of bugs, but never to show their absence! – Dijkstra
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Python development follows a practice that all semantic changes and additions to the language and stdlib are accompanied by appropriate unit tests. Unfortunately Python was in existence for a long time before the practice came into effect. This has left chunks of the stdlib untested which is not a desirable situation to be in. – Python Developer’s Guide
Testing: why?

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Testing: why?

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We must test software in order to:

- Detect problems earlier.
- Facilitate identification of root cause.
- Prevent regressions.
Testing: what & how?

What?

▶ Explicit spec and/or “good behavior”.

▶ Unit testing on . . . basic units.

▶ Integration testing, complete system testing.

▶ Use tools that make it easy and systematic!
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How?
- Unit testing on ... basic units.
- Integration testing, complete system testing.
- Use tools that make it easy and systematic!
Automated testing

From
Automated testing
White box
White box

**Goal**: relevant tests based on the structure of the code.

Idea of **coverage**:
- the testing suite must probe “enough” behaviors.

**Criteria**: lines,
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Criteria: lines, control flow, conditions, values, states, etc.
- Tests are not proofs!
**White box**

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Selecting test values,
- based on code and spec: equivalence classes, boundaries...
- manually (demo: `triangle.ml`)....
White box

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Selecting test values,
based on code and spec: equivalence classes, boundaries...
manually (demo: `triangle.ml`)...or automatically.
Generate “interesting” test values, by symbolic execution and constraint solving. Demo: http://www.pexforfun.com

```csharp
public class Point {
    public readonly int X, Y;
    public Point(int x, int y) { X = x; Y = y; }
}

public class Program {
    public static void Puzzle(Point p) {
        if (p.X * p.Y == 42)
            throw new Exception("Bug!");
    }
}
```

Propose 3 inputs: null, (0,0) and (3,14).
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    }
}

Propose 3 inputs: null, (0,0) and (3,14).
public class Program {
    public static string Puzzle(string value) {
        Contract.Requires(value != null);
        Contract.Ensure(Contract.Result<string>() != null);
        Contract.Ensure(
            char.IsUpper(Contract.Result<string>()[0]));
        return char.ToLower(value[0]) + value.Substring(1);
    }
}

Find inputs that trigger bugs...
public class Program {
    public static string Puzzle(string value) {
        Contract.Requires(value != null);
        Contract.Requires(value=="" ||
                          char.IsLower(value[0]));
        Contract.Ensures(Contract.Result<string>() != null);
        Contract.Ensures(
            Contract.Result<string>()=="" ||
            char.IsUpper(Contract.Result<string>()[0]));
        if (value=="") return value;
        return char.ToUpper(value[0]) + value.Substring(1);
    }
}
using System;

public class Program {
    static int Fib(int x) {
        return x == 0 ? 0 : x == 1 ? 1 :
            Fib(x - 1) + Fib(x - 2);
    }
    public static void Puzzle(int x, int y) {
        if (Fib(x + 27277) + Fib(y - 27277) == 42)
            Console.WriteLine("puzzle solved");
    }
}
Black box
What if we cannot / don’t want to rely on the code?
Black box: TDD

Test driven development: write tests first, then code that passes them.
Black box: TDD

Test driven development: write tests first, then code that passes them.
Black box: test & spec

Tests cannot replace specs, but allow to exploit it more.

Generate tests from specs:
  spec coverage, e.g., cause/consequence, clauses
Black box: randomness and stress

Randomized tests

- Quickcheck, Scalacheck (demo):
  test predicates on random input values
Black box: randomness and stress

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- **Csmith:** compare C compilers on random code samples
  \(\Rightarrow\) no need for a spec (phew!)
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Stress

- Flood a server with requests
- Execution with constrained resources (memory, disk)
- Create latency (network)
Black box: randomness and stress

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Fuzz testing

- Mainly for file formats and protocols
- Test on (partly) randomly generated/modified data
- zzuf (demo), LibFuzzer, afl-fuzz, ...
Chaos engineering

Today’s large distributed systems bring problems for which testing is insufficient. New slogans:

   design for failure and experiment in production.
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Example (Netflix)

- The “Chaos Monkey” tool randomly disables machines/services
- http://principlesofchaos.org
In practice
Tooling

Libraries to write tests more easily:
  xUnit, Scalacheck, Scalatest, etc.

Environments and tools to use them effectively:
  pytest, sbt, hooks & CI, etc.

Demo
Objection 1

Writing tests = wasting time?
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When coding, you’re already writing tests:
  maybe in an interpreter,
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The goal is to preserve such tests, so as to fully exploit them.
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Regression test

Good practice integrating testing and debugging:
before debugging, turn minimized bug into a test;
the test will validate the fix and prevent future regressions.
Objection 2

“That’s easy for a sorting function,
but another story for a server...”

Often, hard to test = poorly designed!

Examples

- Interaction with the filesystem, a database, etc.: sandboxing
- Graphical interface: possibility to script or capture (\textit{xnee})
  beware: testing the interface or the underlying logic?
- Non-functional aspects (time, space): profiling
Conclusion

Summary

▶ Test your code systematically.
▶ Design for unit tests.

What’s next

▶ Exercises:
  ▶ Code FIND with pytest and hypothesis
  ▶ Debug bheap.py with the same tools
▶ Project: each goal must be tested for validation