EN.601.422 / EN.601.622

Software Testing & Debugging

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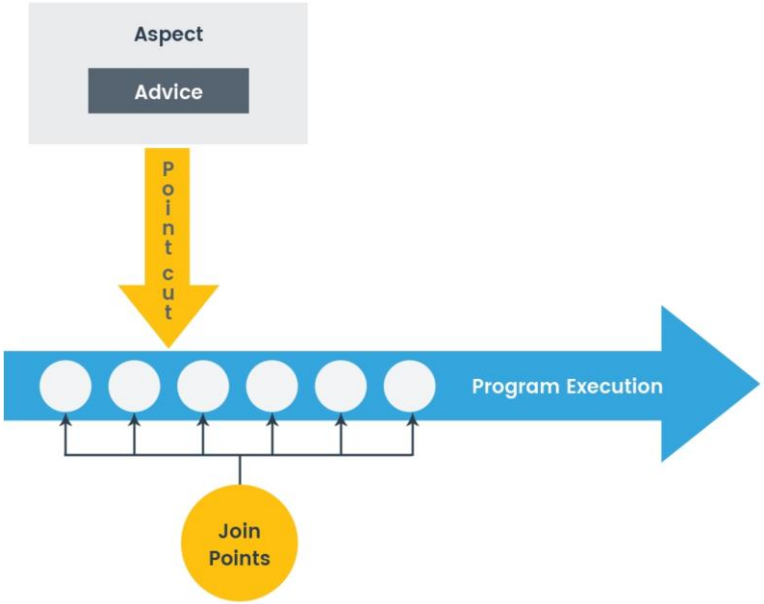
Log with Aspects

- **Aspect-Oriented (AO) Programming**: a programming paradigm that aims to increase modularity by allowing the separation of ***cross-cutting concerns*** from the ***core concern***
- *Basic idea: Separate concerns into individual syntactic entities (aspects)*
- *Aspect code (advice) is woven into the program code at specific places (join points)*
- *The same aspect code can be woven into multiple places (pointcuts)*
  - *e.g.* log all function calls when the function's name begins with “set”



Logging as a Crosscutting Concern

- Logging is a cross-cutting concern: does not have to do anything with the logic of the program → logging is a separate concern
- Implement “logging” as a separate *aspect* that cuts through points of interest in the code and logs events/activities/variable values/etc. of interest.
- Other cross-cutting concerns (i.e., aspects) might be security, data validation, authentication system, synchronization, optimizations etc.

Using Debuggers (aka Observation Tool)

- Logging requires writing and integrating extra code into the program
- Debugger:
  - Getting started fast – without altering the program code at hand
  - Flexible observation of arbitrary events
  - Transient sessions – no code is written

Debuggers

- Debugger: an external observer tool that hooks itself into the execution of the program and observes (possibly manipulates too) the state of the program.
- Debuggers functionalities:
  - Execute the program and make it stop under specific conditions
  - Observe the state of the stopped program
  - Change the state of the program

Debugging Session Using a Debugger

- Before starting the session:
  - Try to develop a *hypothesis* or several hypotheses: explanations for what might be wrong
  - Make note of parts of the code and variables that are involved (i.e., should be investigated) based on your hypothesis/hypotheses
    - What part(s) of program state should be checked
  - Decide on particular points of interest in the program where you like to stop and check things out:
    - **Breakpoint**: when program reaches a breakpoint, it stops (i.e., hands over the control to the debugger) giving you a chance to check things out

Watchpoints and Conditional Breakpoints

- Watchpoints: a data breakpoint
  - Program execution stops and execution control is handed over to the debugger if a variable (or an expression) is read and/or is changed
  - Useful when you want to focus on a specific variable/expression
- Conditional Breakpoint:
  - Program execution stops, and execution control is handed over to the debugger if a certain condition evaluates to true
- Watchpoints and conditional breakpoints are expensive:
  - The debugger must verify the value of watched variable/expression and/or a condition after each instruction
  - Slows down program execution by a factor of 1000

Interactive vs. Postmortem Debugging

- Interactive debuggers allow step-by-step execution and inspection/modification of state
- Postmortem debuggers analyze an application after it has crashed:
  - Analyze the core dump
  - Automated tools available: WinDbg, LLDB, GDB etc.

Simplifying

- Once one has reproduced a problem, one must find out what's relevant:
  - Does the problem really depend on 10,000 lines of input?
  - Does the failure really require this exact schedule?
  - Do we need this sequence of calls?

Why Simplify

- An airplane crashes:
  - Remove passenger seats, does it still crash?
  - Remove coffee machine, does it still crash?
  - Remove the engines, it does not move

engines are relevant!

Simplifying and Circumstances

- For every circumstance of the problem, check whether it is relevant for the problem to occur.
- If it is not, remove it from the problem report or the test case in question.
- Any aspect that may influence a problem is a circumstance:
  - Aspects of the problem environment
  - Individual steps of the problem history

Simplifying by Experimentation

- By experimentation, one finds out whether a circumstance is relevant or not:
- Omit the circumstance and try to reproduce the problem.
- The circumstance is relevant iff the problem no longer occurs.

Mozilla Gecko and a Reported Bug

- Gecko: Mozilla HTML layout engine
- In 1999, there were 370 open problem reports
- Loading an 896-lines HTML crashed the browser
- Much better to work with the smallest possible HTML input file that contains the “failure cause”

Why Simplify

- Ease of communication:
  - A simplified test case is easier to communicate.
- Easier debugging:
  - Smaller test cases result in smaller states and shorter executions.
- Identify duplicates:
  - Simplified test cases subsume several duplicates.


bugzilla.mozilla.org
What’s relevant in here?

The Gecko BugAThon

- New problem reports came in way faster than the Mozilla developers could possibly simplify them or even look at them

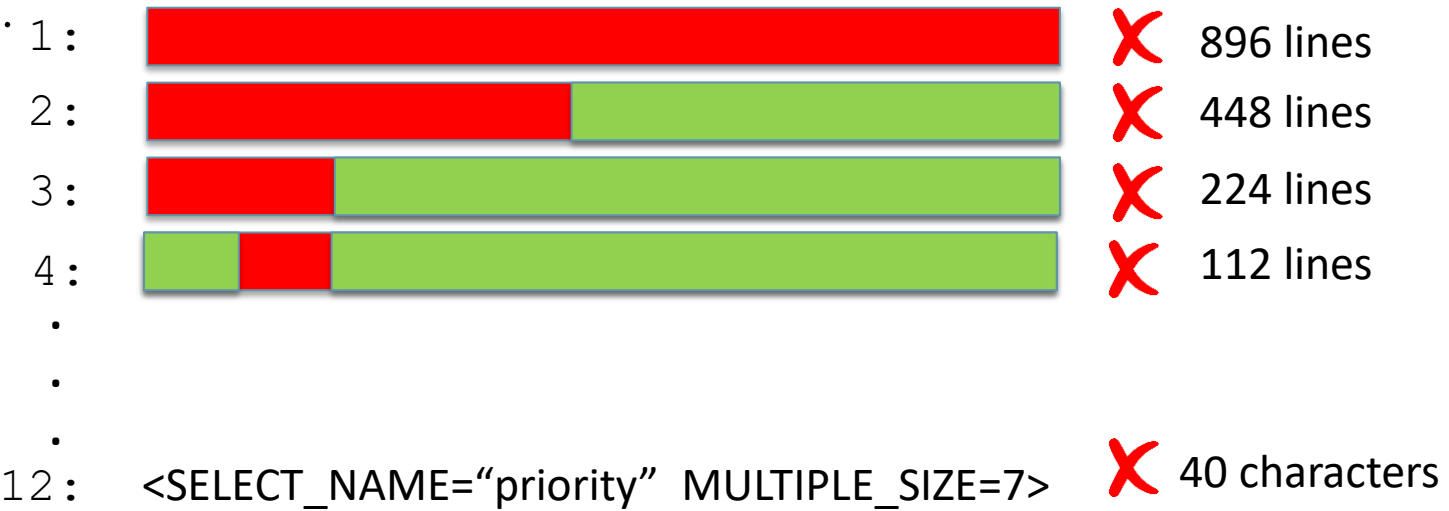
- Eric Krock, the Mozilla product manager, came up with a brilliant idea
  - Download the Web page to your machine.
  - Using a text editor, start removing HTML from the page. Every few minutes, make sure it still reproduces the bug.
  - Code not required to reproduce the bug can be safely removed.
  - When you've cut away as much as you can, you're done.

Rewards

- Asked the users themselves to help with simplifying the bugs:
  - 5 bugs - invitation to the Gecko launch party
  - 10 bugs - the invitation, plus an attractive Gecko stuffed animal
  - 12 bugs - the invitation, plus an attractive Gecko stuffed animal autographed by Rick Gessner, the Father of Gecko
  - 15 bugs - the invitation, plus a Gecko T-shirt
  - 20 bugs - the invitation, plus a Gecko T-shirt signed by the whole raptor team

Binary Search

- Proceed by binary search. Throw away half the input and see if the output is still wrong.
- If not, go back to the previous state and discard the other half of the input.



Simplified Input

<SELECT NAME="priority" MULTIPLE SIZE=7>

- Simplified from 896 lines to one single line
- Required 12 tests only

Benefits

- Ease of communication:
  - All one needs is “<SELECT> tag causes a crash”
- Easier debugging:
  - We can directly focus on the piece of code that renders <SELECT>
- Identify duplicates:
  - Check other test cases whether they’re <SELECT>-related, too.

Automated Simplification

- Manual simplification is slow & boring.
- We have machines for mechanical tasks.
- Basic idea:
  - We set up an automated test that checks whether the failure occurs or not e.g., Mozilla crashes or not
  - We implement a strategy that realizes the binary search

Automated Test

- Launch Mozilla
- Replay (previously recorded) steps from problem report
- Wait to see whether
  - Mozilla crashes (= the test fails)
  - Mozilla still runs (= the test passes)
- If neither happens, the test is *unresolved*

Binary Search

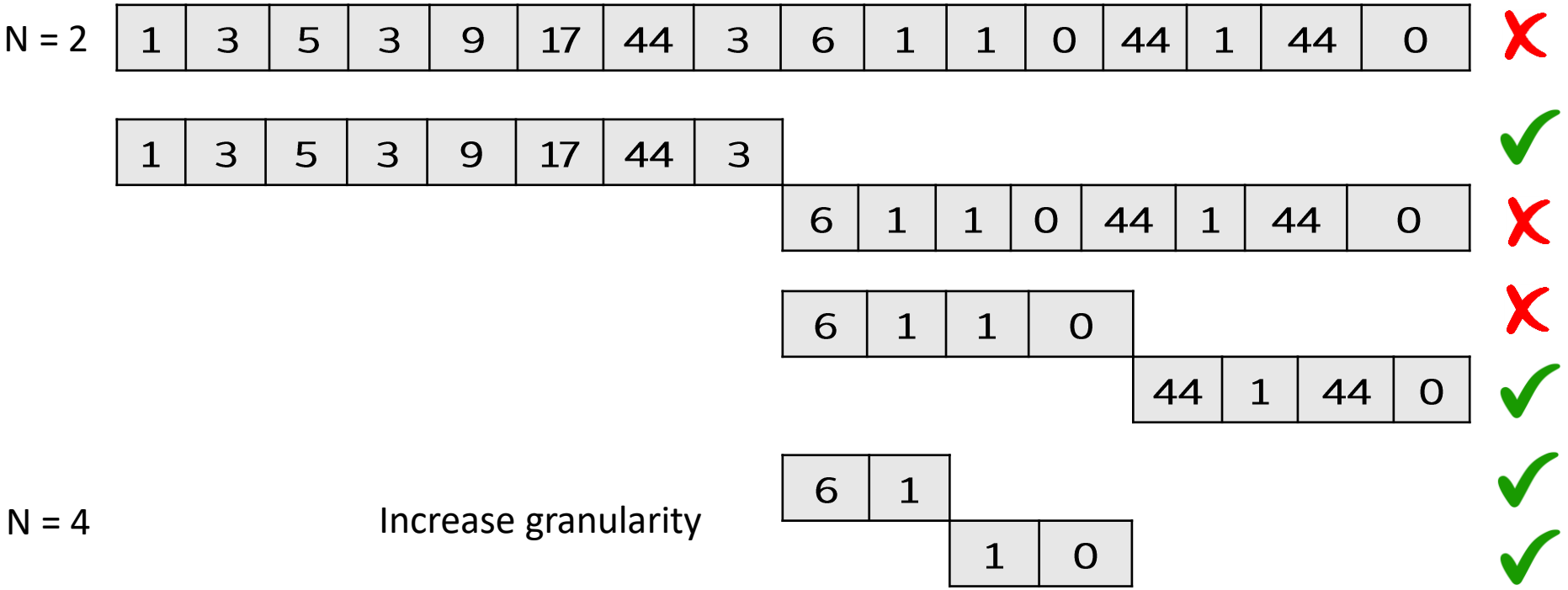
- What do we do if both halves pass?
  - Increase granularity, i.e., break the input into smaller pieces

Example

```
public static int checkSum(int[] a)
```

- is supposed to compute the checksum of an integer array
- gives wrong result, whenever “a” contains two identical consecutive numbers, **but we don’t know that yet**
- we have a failed test case, e.g., from protocol transmission:
  - {1, 3, 5, 3, 9, 17, 44, 3, 6, 1, 1, 0, 44, 1, 44, 0}

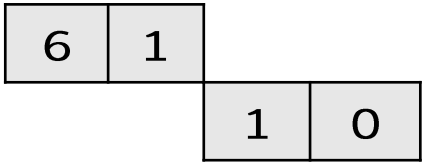
Another Example (N is number of chunks)



Another Example - Continued

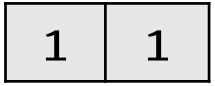
N = 4

Increase granularity



N = 3

Adjust granularity to input size



ddmin Algorithm

- Let **c** be a failing input configuration (sequence of individual inputs)
- **test(c)** runs a test on **c** with possible outcome PASS or FAIL
- **n** is the number of chunks to split **c** into (initially **n = 2**). We will remove one chunk at a time and test the remaining input.

```
ddMin(c, n) :
1. If |c| = 1 return c
```

ddmin Algorithm

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ddMin(c, n) :

1. If |c| = 1 **return c**

Otherwise, systematically remove one chunk c_i at the time. Test the remaining input $\mathbf{c} \setminus c_i$:

2. If there exist some c_i such that test(**c** \ c_i) = FAIL return **ddMin(c \ c_i , max(n-1, 2))**

ddmin Algorithm

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3. Else, if n < |c| return **ddMin(c, min(2n, |c|))**

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ddMin(c, n) :

1. If: |c| = 1 **return c**

// Otherwise, systematically remove one chunk c_i at the time. Test the remaining input **c** \ c_i :

2. If there exist some c_i such that test(**c** \ c_i) = FAIL
return **ddMin(c \ c_i , max(n-1, 2))**

3. Else if: n < |c|
return **ddMin(c, min(2n, |c|))**

4. Else: // (can't split into smaller chunks)
return **c**

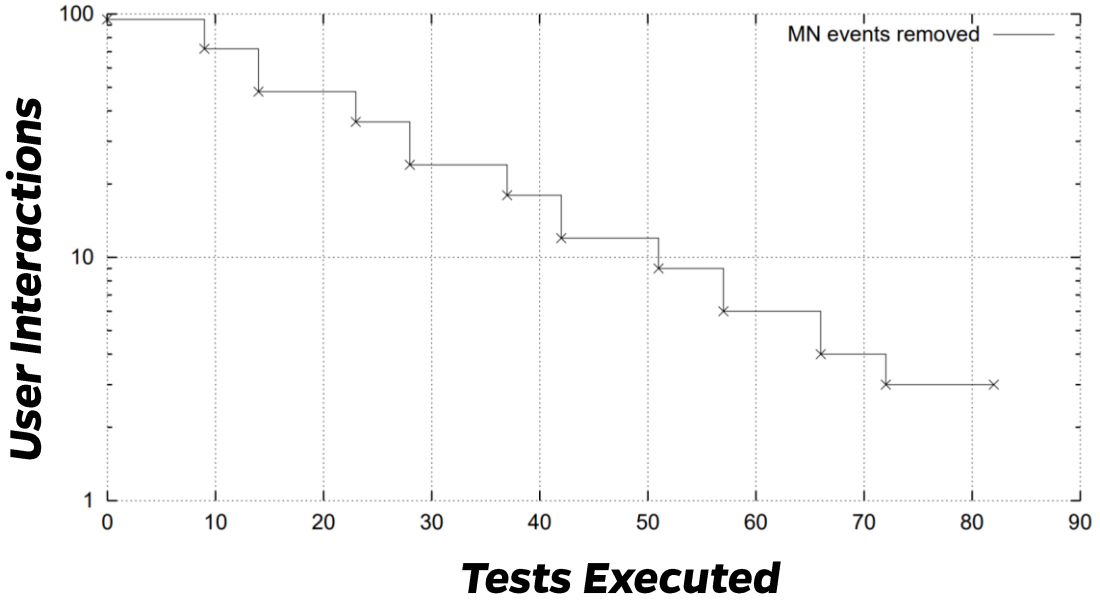
Delta Debugging

- The technique is an instance of *delta debugging*:
  - An approach to isolate failure causes by narrowing down differences (deltas) between runs
- Delta Debugging can be applied to various types of inputs such as:
  - failure-inducing program input, e.g., HTML page
  - failure-inducing user interactions e.g., the key/mouse strokes that make a program crash
  - failure-inducing changes to the program code, e.g., after a failing regression test
  - etc.

Delta Debugging

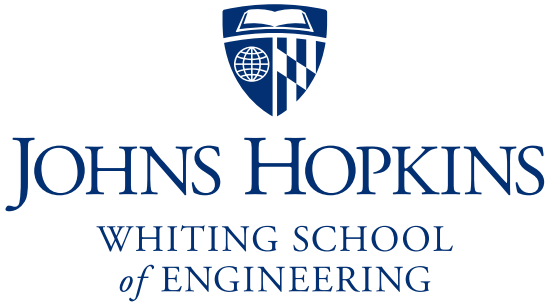
- After 82 tests, **`ddmin`** has simplified the user interactions to 3 events:

  1. Press `P` while holding `Alt`
  2. Press the `left mouse button` on the `Print` button
  3. Release the `left mouse button`



Relevant Reads and Resources

- Recommended Texts
  - “Why Programs Fail”: ch5
- https://www-archive.mozilla.org/newlayout/bugathon.html
- TDA567/DIT082 Chalmers University of Technology
  http://www.cse.chalmers.se/edu/year/2018/course/TDA567/



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