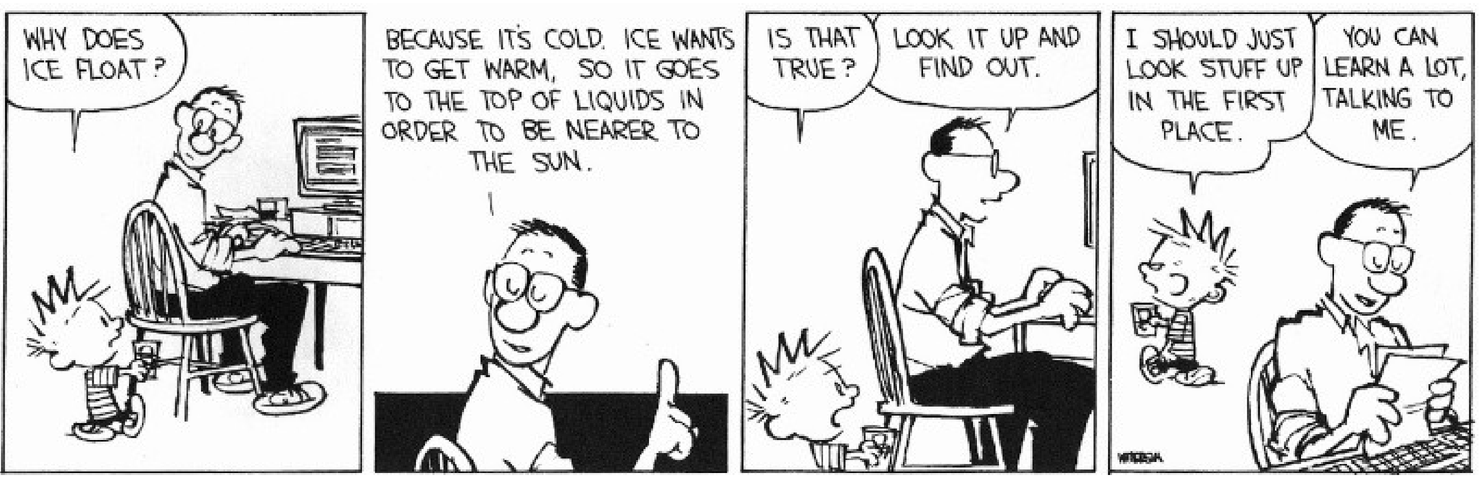
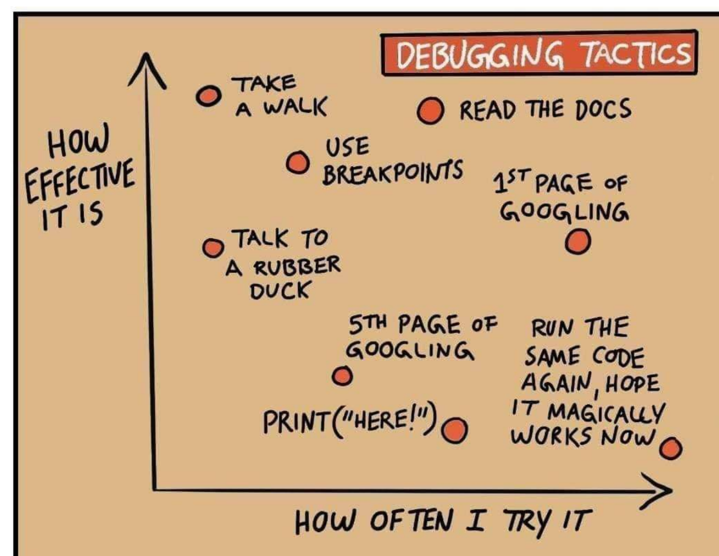
Debugging as Hypothesis Testing



The Story So Far …

- Quality assurance is critical to software engineering
- Defect reports are tracked and assigned to developers for resolution
- Modern software is so huge that simple debugging approaches do not work
- How should we intelligently and scalably approach debugging?

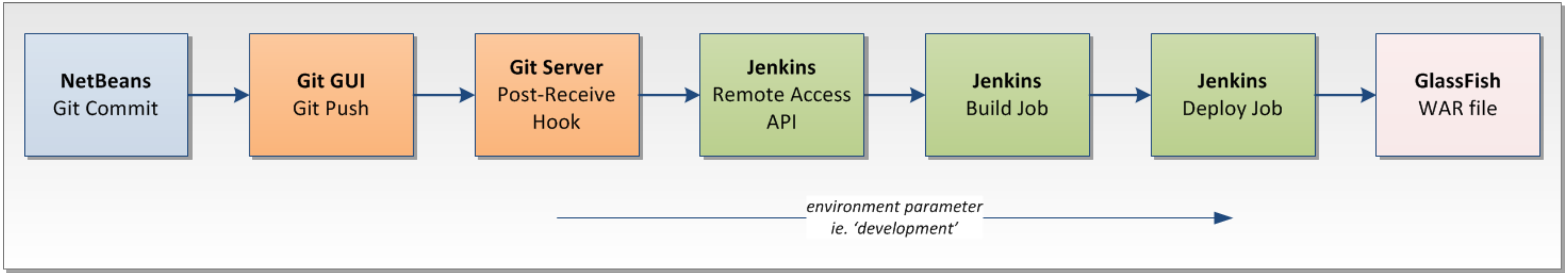


One-Slide Summary

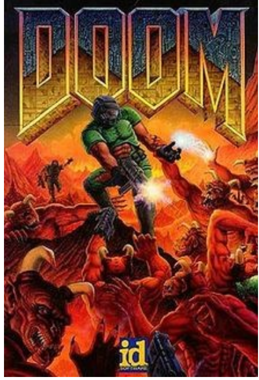
- **Delta debugging** is an automated debugging approach that finds a minimal interesting subset of a given set. It is very efficient.
- Delta debugging is based on divide-and-conquer and relies heavily on critical assumptions (monotonicity, unambiguity, and consistency).
- It can be used to find which code changes cause a bug, to minimize failure-inducing inputs, and even to find harmful thread schedules.

Debugging Case Study

- Consider this deployment pipeline: Git Server to Jenkins to GlassFish application server
  - You have a known-valid test input (NetBeans git commit) that leads to an incorrect WAR file
  - What would you to do determine which pipeline stage has the bug?



Real Life Motivation



- The Mozilla developers had a large number of open bug reports in the queue that were not even simplified
- The Mozilla engineers "faced imminent doom"
- Netscape product management sent out the Mozilla Bug-A-Thon call for volunteers: people who would help simplify bug reports.
  - Simplify → turn bug reports into minimal test cases, where each part of the input matters

Minimizing a Mozilla Bug

- We want something that can simplify this large HTML intput to just “<SELECT>” which causes the crash
- Each character in “SELECT” is relevant (see 20-26)

```
1  <SELECT␣NAME="priority"␣MULTIPLE␣SIZE=7> ✗
2  <SELECT␣NAME="priority"␣MULTIPLE␣SIZE=7> ✔
3  <SELECT␣NAME="priority"␣MULTIPLE␣SIZE=7> ✔
4  <SELECT␣NAME="priority"␣MULTIPLE␣SIZE=7> ✔
5  <SELECT␣NAME="priority"␣MULTIPLE␣SIZE=7> ✗
6  <SELECT␣NAME="priority"␣MULTIPLE␣SIZE=7> ✗
7  <SELECT␣NAME="priority"␣MULTIPLE␣SIZE=7> ✔
8  <SELECT␣NAME="priority"␣MULTIPLE␣SIZE=7> ✔
9  <SELECT␣NAME="priority"␣MULTIPLE␣SIZE=7> ✔
10 <SELECT␣NAME="priority"␣MULTIPLE␣SIZE=7> ✗
11 <SELECT␣NAME="priority"␣MULTIPLE␣SIZE=7> ✔
12 <SELECT␣NAME="priority"␣MULTIPLE␣SIZE=7> ✔
13 <SELECT␣NAME="priority"␣MULTIPLE␣SIZE=7> ✔
14 <SELECT␣NAME="priority"␣MULTIPLE␣SIZE=7> ✔
15 <SELECT␣NAME="priority"␣MULTIPLE␣SIZE=7> ✔
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18 <SELECT␣NAME="priority"␣MULTIPLE␣SIZE=7> ✗
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25 <SELECT NAME="priority"␣MULTIPLE␣SIZE=7> ✔
26 <SELECT NAME="priority"␣MULTIPLE␣SIZE=7> ✗
```
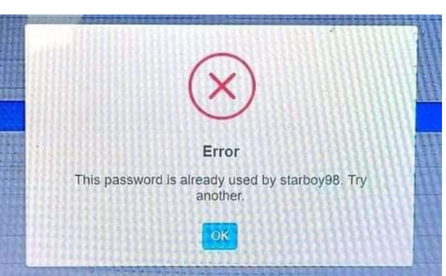
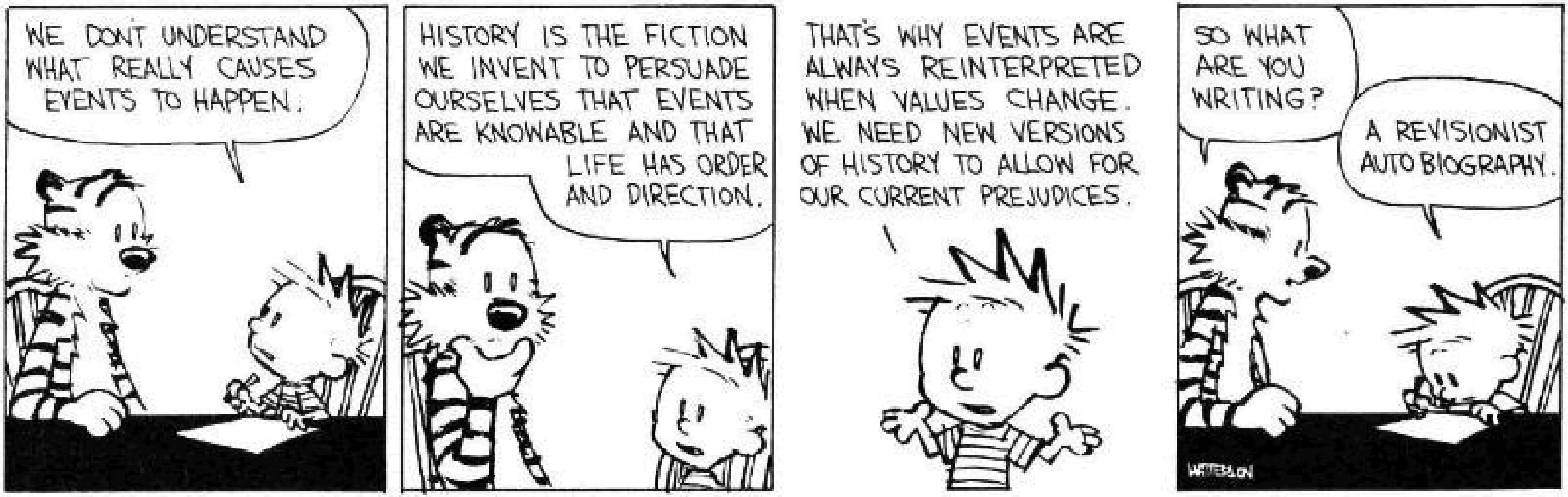



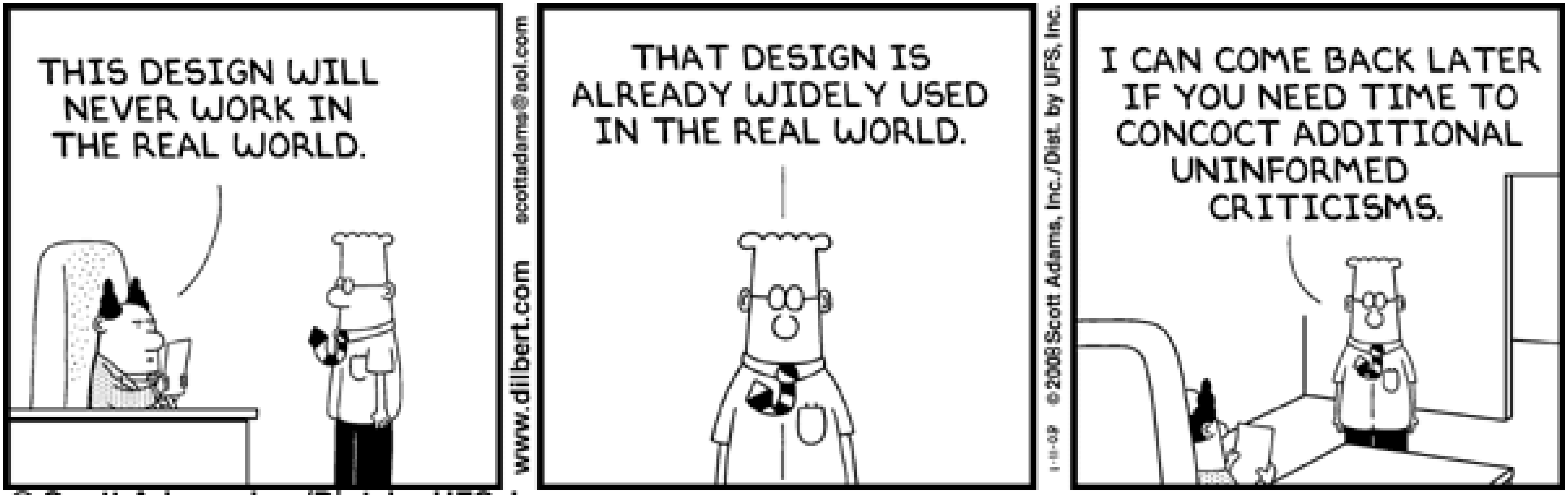
Often people who encounter a bug spend a lot of time investigating which changes to the input file will make the bug go away and which changes will not affect it.

— Richard Stallman, *Using and Porting* GNU CC



Delta Debugging

- Three Problems: One Common Approach
  - Simplifying Failure-Inducing Input
  - Isolating Failure-Inducing Thread Schedules
  - Identifying Failure-Inducing Code Changes



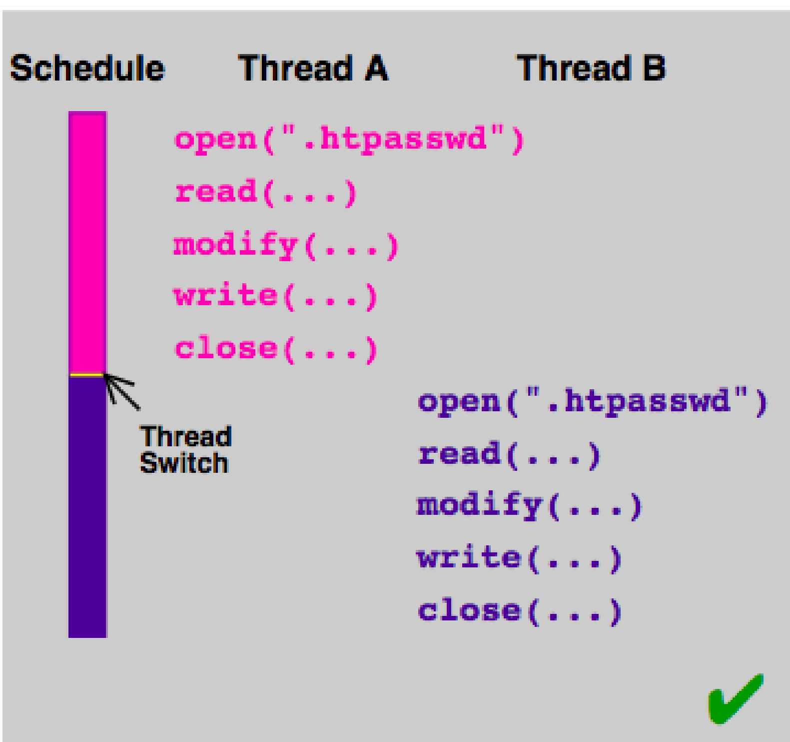
Problem: Failure-Inducing Input

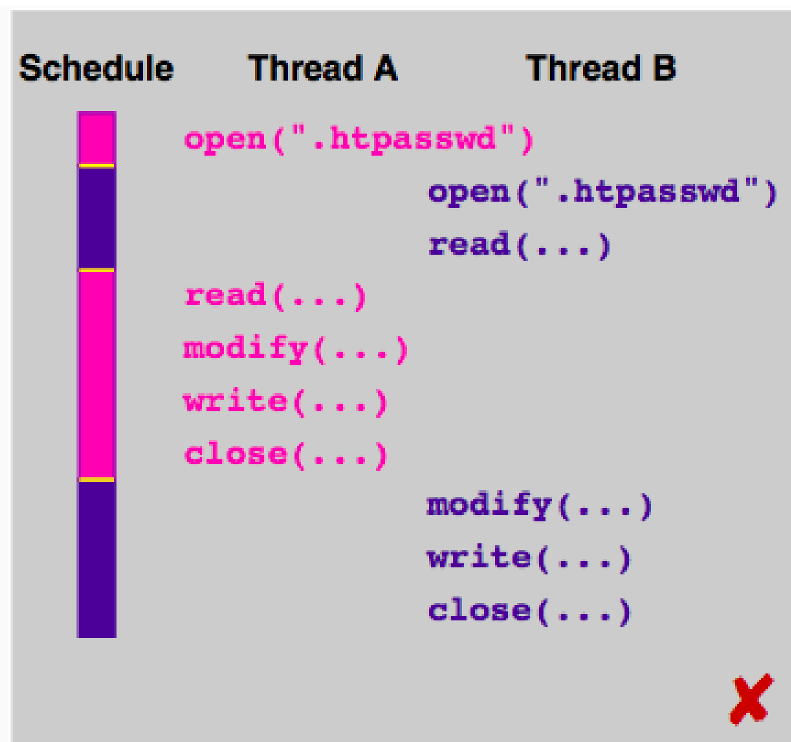
- Having a test input may not be enough
  - Even if you know the suspicious code, the input may be too large to step through
- This HTML input makes a version of Mozilla crash. Which portion is relevant?

```
<td align=left valign=top>
<SELECT NAME="op_sys" MULTIPLE SIZE=7>
<OPTION VALUE="All">All<OPTION VALUE="Windows 3.1">Windows 3.1<OPTION VALUE="Windows 95">Windows 95<OPTION VALUE="Windows
98">Windows 98<OPTION VALUE="Windows ME">Windows ME<OPTION VALUE="Windows 2000">Windows 2000<OPTION VALUE="Windows
NT">Windows NT<OPTION VALUE="Mac System 7">Mac System 7<OPTION VALUE="Mac System 7.5">Mac System 7.5<OPTION VALUE="Mac
System 7.6.1">Mac System 7.6.1<OPTION VALUE="Mac System 8.0">Mac System 8.0<OPTION VALUE="Mac System 8.5">Mac System
8.5<OPTION VALUE="Mac System 8.6">Mac System 8.6<OPTION VALUE="Mac System 9.x">Mac System 9.x<OPTION VALUE="MacOS X">MacOS
X<OPTION VALUE="Linux">Linux<OPTION VALUE="BSDI">BSDI<OPTION VALUE="FreeBSD">FreeBSD<OPTION VALUE="NetBSD">NetBSD<OPTION
VALUE="OpenBSD">OpenBSD<OPTION VALUE="AIX">AIX<OPTION VALUE="BeOS">BeOS<OPTION VALUE="HP-UX">HP-UX<OPTION
VALUE="IRIX">IRIX<OPTION VALUE="Neutrino">Neutrino<OPTION VALUE="OpenVMS">OpenVMS<OPTION VALUE="OS/2">OS/2<OPTION
VALUE="OSF/1">OSF/1<OPTION VALUE="Solaris">Solaris<OPTION VALUE="SunOS">SunOS<OPTION VALUE="other">other</SELECT>
</td>
<td align=left valign=top>
<SELECT NAME="priority" MULTIPLE SIZE=7>
<OPTION VALUE="--">--<OPTION VALUE="P1">P1<OPTION VALUE="P2">P2<OPTION VALUE="P3">P3<OPTION VALUE="P4">P4<OPTION
VALUE="P5">P5</SELECT>
</td>
<td align=left valign=top>
<SELECT NAME="bug_severity" MULTIPLE SIZE=7>
<OPTION VALUE="blocker">blocker<OPTION VALUE="critical">critical<OPTION VALUE="major">major<OPTION
VALUE="normal">normal<OPTION VALUE="minor">minor<OPTION VALUE="trivial">trivial<OPTION VALUE="enhancement">enhancement</SELECT>
</tr>
</table>
```

Problem: Thread Scheduling

- Multithreaded programs can be non-deterministic
  - Can we find simple, bug-inducing thread schedules?





Problem: Code Changes

- A new version of GDB has a UI bug
  - The old version does not have that bug
- 178,000 lines of code have been modified between the two versions
  - Where is the bug?
  - These days: continuous integration testing helps
    - … but does not totally solve this. Why?

```
diff -r gdb-4.16/gdb/infcmd.c gdb-4.17/gdb/infcmd.c
1239c1278
< "Set arguments to give program being debugged when it is started.\n\
---
> "Set argument list to give program being debugged when it is started.\n\
```

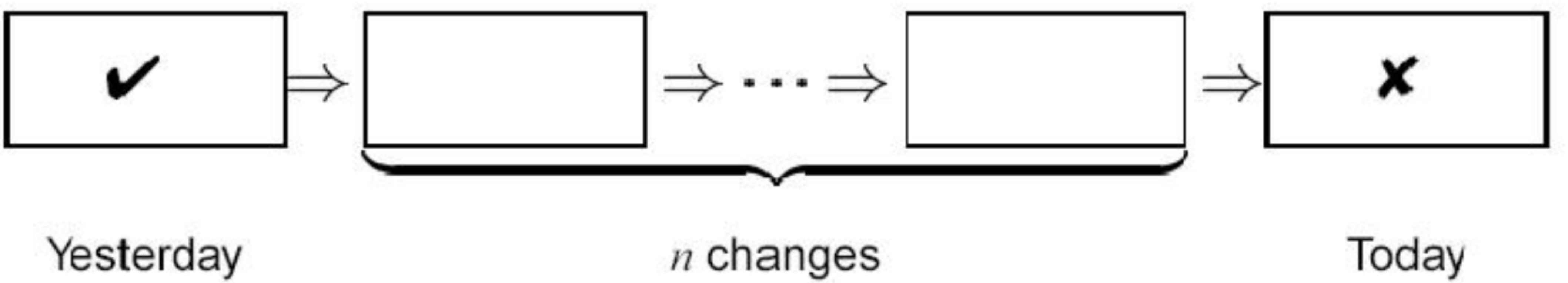
What is a Difference?

- With respect to debugging, a **difference** is a change in the program configuration or state that may lead to alternate observations
  - Difference in the input: different character or bit in the input stream
  - Difference in thread schedule: difference in the time before a given thread preemption is performed
  - Difference in code: different statements or expressions in two versions of a program
  - Difference in program state: different values of internal variables

Unified Solution

- Abstract Debugging Problem:
  - Find which part of something (= which difference, which input, which change) determines the failure
  - "Find the smallest subset of a given set that is still interesting"
- Divide and Conquer
  - Applied to: working and failing inputs, code versions, thread schedules, program states, etc.

Yesterday, My Program Worked Today, It Does Not

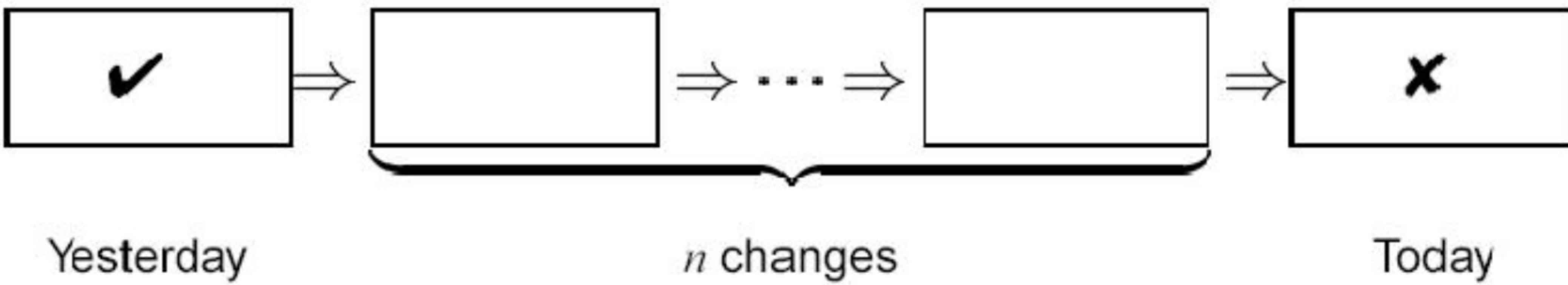


- We will iteratively
  - Hypothesize that a small subset is interesting
    - Example: change set {1,3,8} causes the bug
  - Run tests to falsify that hypothesis

Delta Debugging

- Given
  - a set ***C*** = $\{c_1, \ldots, c_n\}$ (of changes)
  - a function ***Interesting*** : C → {Yes, No}
  - Interesting(C) = Yes , Interesting({}) = No
  - Interesting is monotonic, unambiguous and consistent (more on these later)
- The **delta debugging** algorithm returns a minimal Interesting subset **M** of C:
  - Interesting(M) = Yes
  - For all m ⊂ M, Interesting(M - m) = No

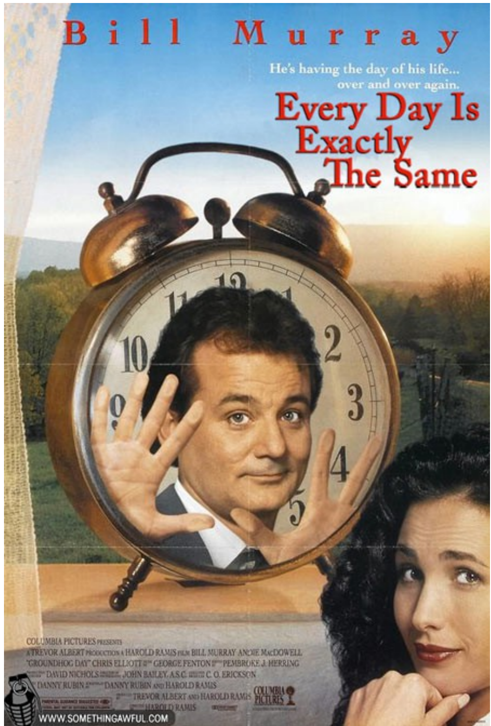
Example Use of Delta Debugging



- C = the set of *n* changes
- Interesting(X) = Apply the changes in X to Yesterday's version and compile. Run the result on the test. If it fails, return “Yes” (X is an interesting failure-inducing change set), otherwise return “No” (X is too small and does not induce the failure)

Naive Approach

- We could just try all subsets of C to find the smallest one that is Interesting
  - Problem: if |C| = N, this takes 2^N time
  - Recall: real-world software is huge
- We want a polynomial-time solution
  - Ideally one that is more like log(N)
  - Or we'll loop for what feels like forever



Algorithm Candidate

```
/* Precondition: Interesting({c_1 ... c_n}) = Yes */
DD({c_1, ..., c_n}) =
  if n = 1 then return {c_1}
  let P1 = {c_1, ... c_n/2}
  let P2 = {c_n/2+1, ..., c_n}
  if Interesting(P1) = Yes
    then return DD(P1)
    else return DD(P2)
```

So far, this is just binary search! It won't work if you need a big subset to be Interesting.

Useful Assumptions

- Any subset of changes may be Interesting
  - Not just singleton subsets of size 1 (cf. bsearch)
- Interesting is **Monotonic**
  - Interesting(X) → Interesting(X ∪ {c})
- Interesting is **Unambiguous**
  - Interesting(X) & Interesting(Y) → Interesting(X ∩ Y)
- Interesting is **Consistent**
  - Interesting(X) = Yes or Interesting(X) = No
  - (Some formulations: Interesting(X) = Unknown)

Delta Debugging Insights

- Basic Binary Search
  - Divide C into P1 and P2
  - If Interesting(P1) = Yes then recurse on P1
  - If Interesting(P2) = Yes then recurse on P2
- At most one case can apply (by Unambiguous)
- By Consistency, the only other possibility is
  - (Interesting(P1) = No) *and* (Interesting(P2) = No)
  - What happens in such a case?

Interference

- By Monotonicity
  - If Interesting(P1) = No and Interesting(P2) = No
  - Then no subset of P1 alone or subset of P2 alone is Interesting
- So the Interesting subset must use a combination of elements from P1 and P2
- In Delta Debugging, this is called **interference**
  - Basic binary search does *not* have to contend with this issue

Interference Insight

(hardest part of this lecture?)

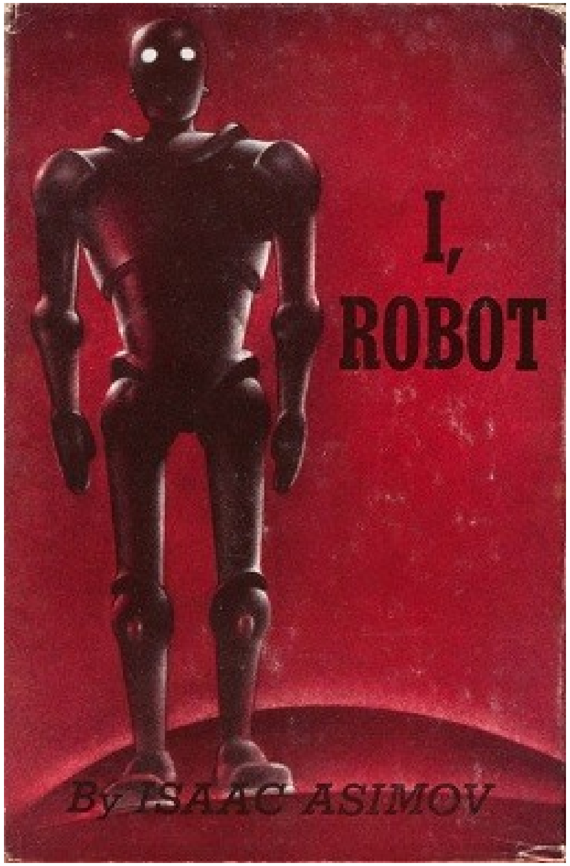
- Consider P1
  - Find a minimal subset D2 of P2
  - Such that Interesting($P1 \cup D2$) = Yes
- Consider P2
  - Find a minimal subset D1 of P1
  - Such that Interesting($P2 \cup D1$) = Yes
- Then by Unambiguous
  - Interesting($(P1 \cup D2) \cap (P2 \cup D1)$) = Interesting($D1 \cup D2$) is also minimal

Trivia: Public Service Announcements

- The United States Forest Service's ursine mascot first appeared in 1944. Give his catch-phrase safety message.

Q: Books (726 / 842)

- Paraphrase any one of Isaac Asimov's 1942 **Three Laws of Robotics**.



Trivia: Football

(student “memorial”)

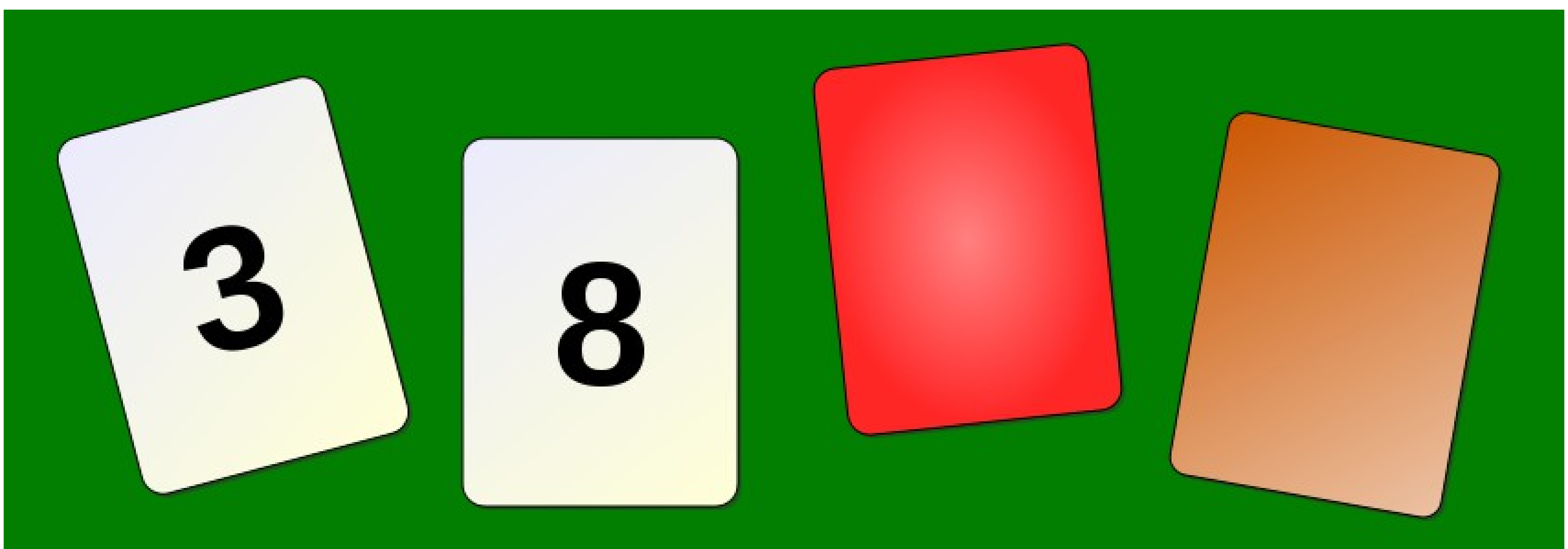
- This Brazillian footballer, widely regarded as the greatest player of all time, is the most successful league goal scorer in the world (541 league goals). He scored 1281 goals in 1363 games in total, and was sometimes known as Pérola Negra or O Rei do Futebol. Sports writer Jeff Powell said of him: “The most wondrous player of all consecrated Brazil as the cathedral of the beautiful game. Brazil '70 were a team of superstars dedicated not just to a cause but an ideal, a dream of what football should be.”

Real-World Languages

- These languages, of which there are about 250, are often mutually intelligible and constitute a major branch of the Niger-Congo languages. They are spoken largely in central, east and southern Africa. Popular examples include Swahili, with 80 million speakers, Shona, with 11 million, and Zulu, with 10 million. They commonly use words such as muntu or mutu for “person”. Words such as bongos, chimpanzee, gumbo, jumbo, mambo, rumba and safari come from these languages.

Psychology: Deductive Reasoning

- You are shown a set of four cards placed on a table, each of which has a number on one side and a colored patch on the other side. The visible faces of the cards show 3, 8, red and brown. Which card(s) must you turn over to test the truth of the proposition that if a card shows an even number on one face, then its opposite face is red?



Psychology: Unrelated

- Who do you investigate in a bar to test the truth of the proposition “if you have alcohol you must be over 18”?

Psychology: Wason Selection Task

- Most participants have trouble solving the problem in general but can solve it easily when it involves policing a social rule
  - In the original study, < 10% of subjects found the correct solution (follow-on studies, < 25%)
  - However, 75% get the drinking age problem correct
  - Or a similar but unfamiliar “benefit accepted” vs. “cost not paid” social context
    - (e.g., “to eat cassava root you must have a tattoo”)

[Wason, P. C. (1968). "Reasoning about a rule". Quarterly Journal of Experimental Psychology. 20 (3): 273–281.]

Psychology: Social Contract

- "We do not have a general-purpose ability to detect violations of conditional rules. But human reasoning is well-designed for detecting violations of conditional rules when these can be interpreted as cheating on a social contract."
  - (e.g., *must* pay cost, *may* claim benefit)
- Implications for SE: Myriad for defect detection, groupwork, etc.

[Cosmides, L.; Tooby, J. (1992). "Cognitive Adaptions for Social Exchange". 163-228.]

Delta Debugging Algorithm

DD$(P, \{c_1, \ldots, c_n\}) =$

if $n = 1$ then return $\{c_1\}$

let $P1 = \{c_1, \ldots c_{n/2}\}$

let $P2 = \{c_{n/2+1}, \ldots, c_n\}$

if Interesting$(P \cup P1)$ = Yes then return $DD(P, P1)$

if Interesting$(P \cup P2)$ = Yes then return $DD(P, P2)$

else return $DD(P \cup P2, P1) \cup DD(P \cup P1, P2)$

Delta Debugging Algorithm

$DD(P, \{c_1, \ldots, c_n\}) =$

if $n = 1$ then return $\{c_1\}$

let $P1 = \{c_1, \ldots c_{n/2}\}$

let $P2 = \{c_{n/2+1}, \ldots, c_n\}$

if Interesting($P \cup P1$) = Yes then return DD(P,P1)

if Interesting($P \cup P2$) = Yes then return DD(P,P2)

else return DD($P \cup P2$, P1) $\cup$ DD($P \cup P1$, P2)

P helps us handle interference.
P is a subset of changes we are including when calling Interesting().
P is passed in to recursive DD calls.
P starts as { }.

Example: {3,6} Is Smallest Interesting Subset of {1, …, 8}

1	2	3	4	5	6	7	8	Interesting?

Example: Use DD to find the smallest interesting subset of {1, …, 8}

Example: {3,6} Is Smallest Interesting Subset of {1, …, 8}

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Interesting?**
1	2	3	4					
				5	6	7	8	

First Step:
Partition C = {1, …, 8} into
P1 = {1, …, 4} and P2 = {5, …, 8}

Example: {3,6} Is Smallest Interesting Subset of {1, …, 8}

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Interesting?**
1	2	3	4					???
				5	6	7	8	???

Second Step:
Test P1 and P2

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1	2	3	4					No
				5	6	7	8	No

Interference! Sub-Step:
Find minimal subset D1
of P1 such that
Interesting(D1 + P2)

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1	2	3	4	5	6	7	8	Interesting?
1	2	3	4					No
				5	6	7	8	No

P = P2 = {5, 6, 7, 8}
We'll include P when checking Interesting

Interference! Sub-Step:
Find minimal subset D1 of P1 such that Interesting(D1 + P2)

Example: {3,6} Is Smallest Interesting Subset of {1, …, 8}

1	2	3	4	5	6	7	8	Interesting?
1	2	3	4					No
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		3	4	5	6	7	8	???

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				5	6	7	8	No
1	2			5	6	7	8	No
		3	4	5	6	7	8	Yes

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1	2	3	4	5	6	7	8	Interesting?
1	2	3	4					No
				5	6	7	8	No
1	2			5	6	7	8	No
		3	4	5	6	7	8	Yes
		3		5	6	7	8	???

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1	2	3	4					No
				5	6	7	8	No
1	2			5	6	7	8	No
		3	4	5	6	7	8	Yes
		3		5	6	7	8	Yes

Example: {3,6} Is Smallest Interesting Subset of {1, …, 8}

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Interesting?**
1	2	3	4					No
				5	6	7	8	No
1	2			5	6	7	8	No
		3	4	5	6	7	8	Yes
		3		5	6	7	8	Yes

D1 = {3}

Example: {3,6} Is Smallest Interesting Subset of {1, …, 8}

1	2	3	4	5	6	7	8	Interesting?
1	2	3	4					No
				5	6	7	8	No
1	2			5	6	7	8	No
		3	4	5	6	7	8	Yes
		3		5	6	7	8	Yes
1	2	3	4	5	6			Yes

D1 = {3}

Now find D2!

P = P1 = {1, 2, 3, 4}
We'll include P when checking Interesting

Example: {3,6} Is Smallest Interesting Subset of {1, …, 8}

1	2	3	4	5	6	7	8	Interesting?
1	2	3	4					No
				5	6	7	8	No
1	2			5	6	7	8	No
		3	4	5	6	7	8	Yes
		3		5	6	7	8	Yes
1	2	3	4	5	6			Yes
1	2	3	4	5				???

D1 = {3}

Example: {3,6} Is Smallest Interesting Subset of {1, …, 8}

1	2	3	4	5	6	7	8	Interesting?
1	2	3	4					No
				5	6	7	8	No
1	2			5	6	7	8	No
		3	4	5	6	7	8	Yes
		3		5	6	7	8	Yes
1	2	3	4	5	6			Yes
1	2	3	4	5				No

D1 = {3}

Example: {3,6} Is Smallest Interesting Subset of {1, …, 8}

1	2	3	4	5	6	7	8	Interesting?
1	2	3	4					No
				5	6	7	8	No
1	2			5	6	7	8	No
		3	4	5	6	7	8	Yes
		3		5	6	7	8	Yes
1	2	3	4	5	6			Yes
1	2	3	4	5				No
1	2	3	4		6			???

D1 = {3}

Example: {3,6} Is Smallest Interesting Subset of {1, …, 8}

1	2	3	4	5	6	7	8	Interesting?
1	2	3	4					No
				5	6	7	8	No
1	2			5	6	7	8	No
		3	4	5	6	7	8	Yes
		3		5	6	7	8	Yes
1	2	3	4	5	6			Yes
1	2	3	4	5				No
1	2	3	4		6			Yes

D1 = {3}

Example: {3,6} Is Smallest Interesting Subset of {1, …, 8}

1	2	3	4	5	6	7	8	Interesting?
1	2	3	4					No
				5	6	7	8	No
1	2			5	6	7	8	No
		3	4	5	6	7	8	Yes
		3		5	6	7	8	Yes
1	2	3	4	5	6			Yes
1	2	3	4	5				No
1	2	3	4		6			Yes

D1 = {3}
D2 = {6}

Example: {3,6} Is Smallest Interesting Subset of {1, …, 8}

1	2	3	4	5	6	7	8	Interesting?
1	2	3	4					No
				5	6	7	8	No
1	2			5	6	7	8	No
		3	4	5	6	7	8	Yes
		3		5	6	7	8	Yes
1	2	3	4	5	6			Yes
1	2	3	4	5				No
1	2	3	4		6			Yes

D1 = {3}
D2 = {6}

Final Answer:
{3, 6}

Algorithmic Complexity

- If a single change induces the failure
  - DD is logarithmic: 2 * log |C|
  - Why?
- Otherwise, DD is linear
  - Assuming constant time per Interesting() check
  - Is this realistic? (cf. “AOTBE”)
- If Interesting can return Unknown
  - DD is quadratic: $|C|^2 + 3|C|$
  - If all tests are Unknown except last one (unlikely)

Questioning Assumptions

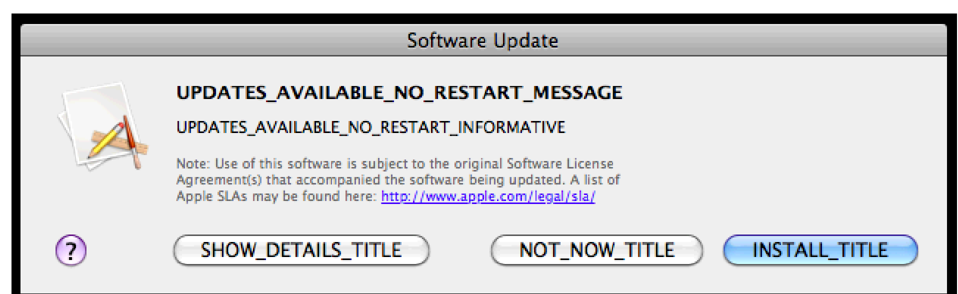
(assumptions are restated here for convenience)

- All three key assumptions are questionable
- Interesting is **Monotonic**
  - Interesting(X) → Interesting(X ∪ {c})
- Interesting is **Unambiguous**
  - Interesting(X) & Interesting(Y) → Interesting(X ∩ Y)
- Interesting is **Consistent**
  - Interesting(X) = Yes or Interesting(X) = No
  - (Some formulations: Interesting(X) = Unknown)

Ambiguity

(a 481 student found this counterexample!)

- ~~Unambiguous: the interesting failure is caused by one subset (and not independently by two disjoint subsets)~~
- What if the world is ambiguous?
- Then DD (as presented here) may *not* find an Interesting subset
- Hint: trace DD on Interesting({2, 8}) = yes, Interesting({3, 6}) = yes, but Interesting({2, 8} intersect {3, 6}) = no.
  - DD returns {2,6} :-(.



Not Monotonic

- ~~Montonic: If X is Interesting, any superset of X is interesting~~
- What if the world is not monotonic?
  - For example, Interesting({1,2}) = Yes but Interesting({1,2,3,4}) = No
- Then DD will find *an* Interesting subset
  - Thought questions: Will it be minimal? How long will it take?

Inconsistency

- ~~Consistent: We can evaluate every subset to see if it is Interesting or not~~
  - What if the world is not consistent?
- Example: we are minimizing changes to a program to find patches that makes it crash
  - Some subsets may not build or run!
  - Integration Failure: a change may depend on earlier changes
  - Construction failure: some subsets may yield programs with parse errors or type checking errors (cf. HW3!)
  - Execution failure: program executes strangely or does not terminate, test outcome is unresolved

Spotting Assumptions (1/2)

(special thanks to Daniel Hoekwater!)

- Let Interesting(X) = "summing *all* integers in X yields 0"
  - So {5, 4, 3, 2, -2, -3, -4, -5} and { -5, 2, 3} are interesting, but { -2, 2, 5} is not.
- Run DD on {5, 4, 3, 2, -2, -3, -4, -5}
- DD *might* return M = { 5, -2, -3 }
  - It looks promising: M is interesting, and some smaller subsets like { 3, -2 } are non-Interesting
- Note, however, that {2, -2} is a smaller subset of M that is interesting!
  - This is because Interesting is not Monotonic and is not Unambiguous. (Exam practice: Why?)

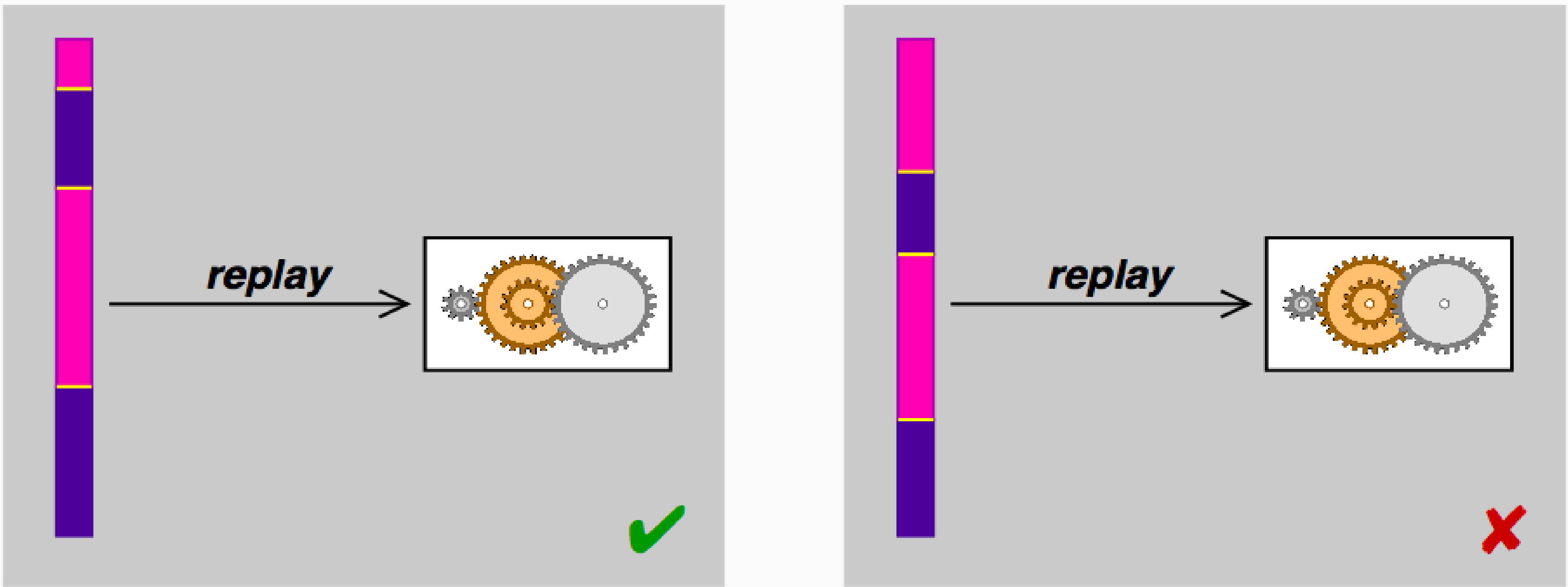
Spotting Assumptions (2/2)

(special thanks to Daniel Hoekwater!)

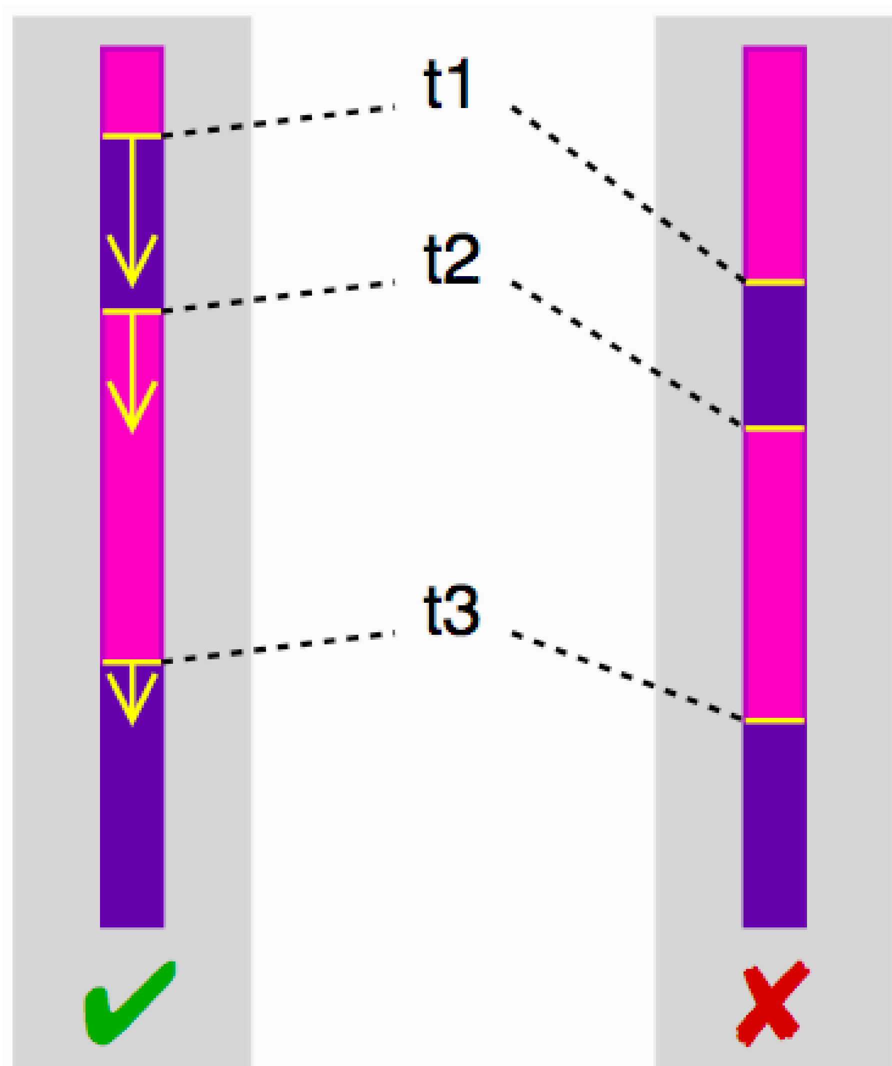
- Let Interesting(X) = "adding *some* integers in X yields 0"
  - So { -2, 2, 5} is interesting (because of subset {-2,2})
- In this case, Interesting is Monotonic but is not Unambiguous
  - Exam practice: Why?
- Note how a slight change in the definition of Interesting changes whether it or not it satisfies certain assumptions
  - Compare this slide to the previous slide
- (Also recall: an empty set cannot be interesting in DD. That violates the "yesterday, my program worked" assumption.)

Delta Debugging Thread Schedules

- DejaVu tool by IBM, CHESS by Microsoft, etc.
- The thread schedule becomes part of the input
- We can control when the scheduler preempts one thread



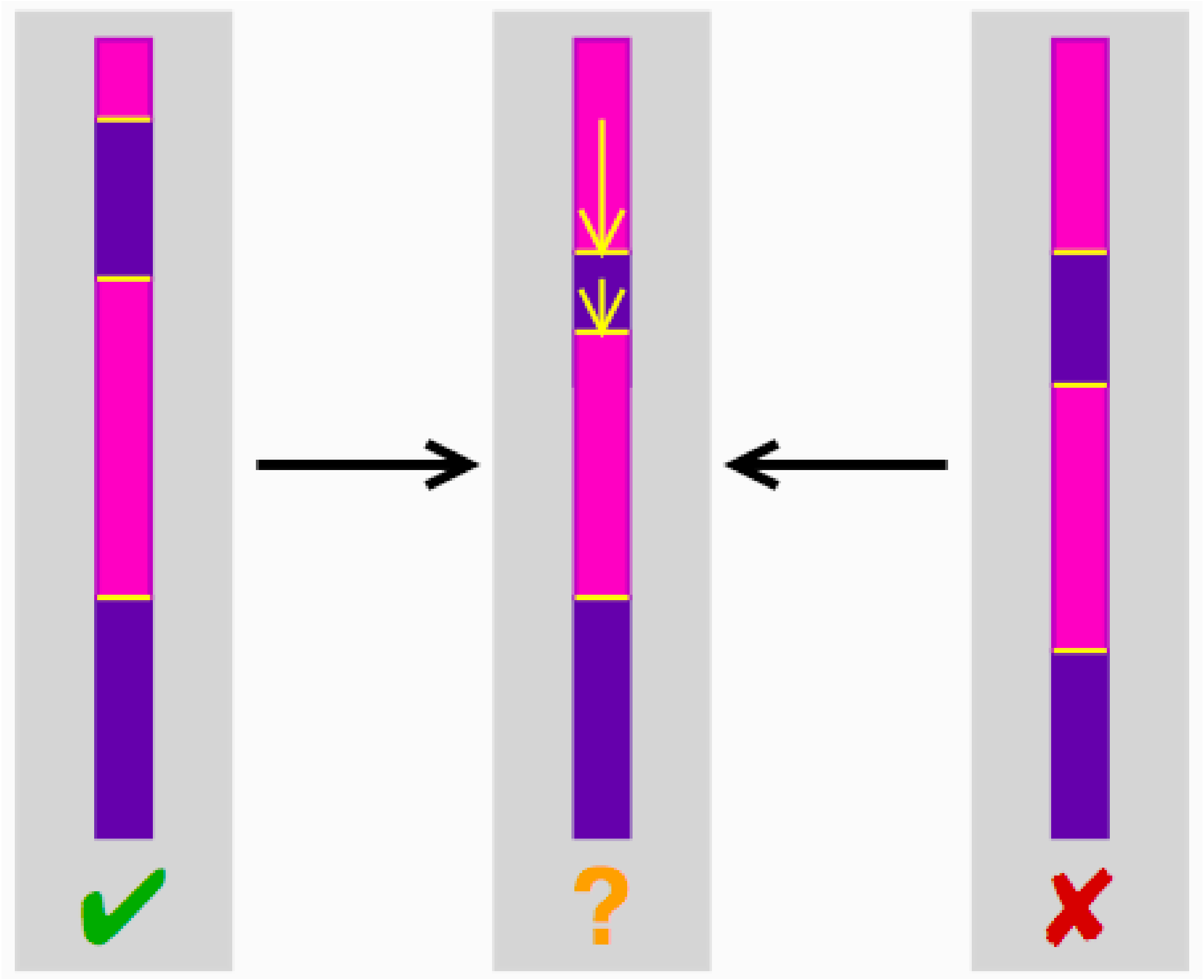
Differences in Thread Scheduling



- Starting point
  - Passing run
  - Failing run
- Differences (for t1)
  - T1 occurs in passing run at time 254
  - T1 occurs in failing run at time 278

Differences in Thread Scheduling

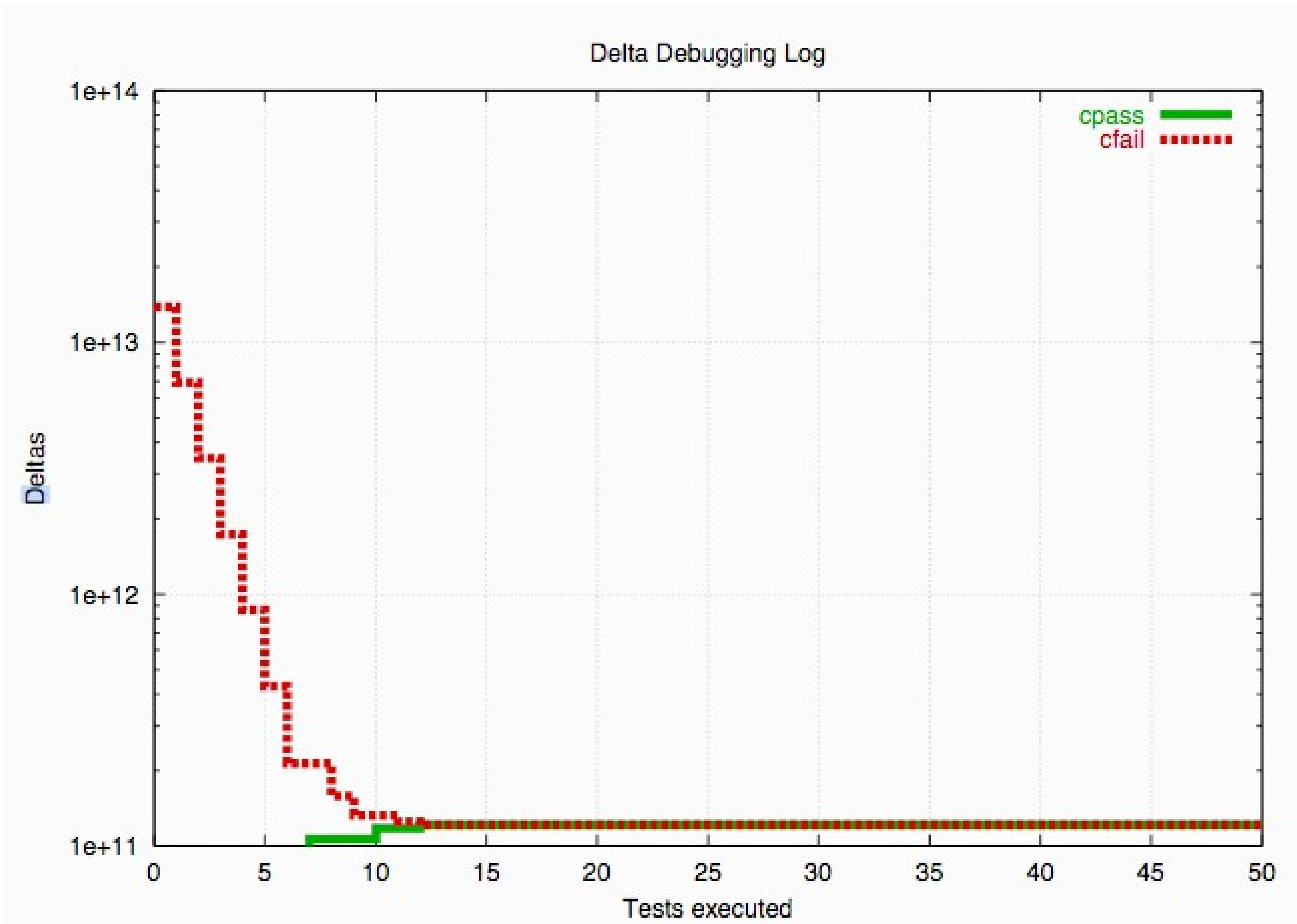
- We can build new test cases by mixing the two schedules to isolate the relevant differences



Does It Work?

- Test #205 of SPEC JVM98 Java Test Suite
  - Multi-threaded raytracer program
  - Simple race condition
  - Generate random schedules to find a passing schedule and a failing schedule (to get started)
- Differences between passing and failing
  - 3,842,577,240 differences (!)
  - Each difference moves a thread switch time by +1 or -1

DD Isolates One Difference After 50 Probes (< 30 minutes)



Pin-Pointing The Failure

- The failure occurs iff thread switch #33 occurs at yield point 59,772,127 (line 91) instead of 59,772,126 (line 82) → race on *which variable*?

```
25  public class Scene { ...
44      private static int ScenesLoaded = 0;
45      (more methods...)
81      private
82      int LoadScene(String filename) {
84          int OldScenesLoaded = ScenesLoaded;
85          (more initializations...)
91          infile = new DataInputStream(...);
92          (more code...)
130         ScenesLoaded = OldScenesLoaded + 1;
131         System.out.println("" +
                ScenesLoaded + " scenes loaded.");
132         ...
134     }
135     ...
733 }
```

should be "Critical Section" but is not

Minimizing Input

- GCC version 2.95.2 on x86/Linux with certain optimizations crashed on a legitimate C program
  - Note: GCC crashes, not the program!

```
#define SIZE 20

double mult(double z[], int n)
{
  int i, j;

  i = 0;
  for (j = 0; j < n; j++) {
    i = i + j + 1;
    z[i] = z[i] * (z[0] + 1.0);
  }

  return z[n];
}

void copy(double to[], double from[], int count)
{
   int n = (count + 7) / 8;
   switch (count % 8) do {
      case 0: *to++ = *from++;
      case 7: *to++ = *from++;
      case 6: *to++ = *from++;
      case 5: *to++ = *from++;
      case 4: *to++ = *from++;
      case 3: *to++ = *from++;
      case 2: *to++ = *from++;
      case 1: *to++ = *from++;
   } while (--n > 0);

   return mult(to, 2);
}

int main(int argc, char *argv[])
{
   double x[SIZE], y[SIZE];
   double *px = x;

   while (px < x + SIZE)
      *px++ = (px - x) * (SIZE + 1.0);

   return copy(y, x, SIZE);
}
```

Delta Debugging to the Rescue

- With 731 probes (< 60 seconds), minimized to:

$\mathbf{t}$(double z[],int n){int i,j;for(;;){$i = i + j + 1$;$z[i] = z[i] * (z[0] + 0)$;}return $z[n]$;}

- GCC has many options
  - Run DD again to find which are relevant

–ffloat-store	*–fno-default-inline*	*–fno-defer-pop*
–fforce-mem	*–fforce-addr*	*–fomit-frame-pointer*
–fno-inline	*–finline-functions*	*–fkeep-inline-functions*
–fkeep-static-consts	*–fno-function-cse*	*–ffast-math*
–fstrength-reduce	*–fthread-jumps*	*–fcse-follow-jumps*
–fcse-skip-blocks	*–frerun-cse-after-loop*	*–frerun-loop-opt*
–fgcse	*–fexpensive-optimizations*	*–fschedule-insns*
–fschedule-insns2	*–ffunction-sections*	*–fdata-sections*
–fcaller-saves	*–funroll-loops*	*–funroll-all-loops*
–fmove-all-movables	*–freduce-all-givs*	*–fno-peephole*

Go Try It Out: Eclipse Integration

Automated Debugging in Eclipse

We realized two Eclipse plug-ins that automatically determine why your program fails:

- in the input and
- in the program history.

These plug-ins integrate with JUnit tests: As soon as a test fails, they automatically determine the failure cause. You don't even have to press a button—just wait for the diagnosis.

DDinput: Failure-Inducing Input

Find out which part of the input causes your program to fail:

> *The program fails when the input contains <SELECT>.*

This plug-in applies Delta Debugging to program inputs, as described in Simplifying and Isolating Failure-Inducing Input.

Available for download.

DDchange: Failure-Inducing Changes

Find out which change causes your program to fail:

> *The change in Line 45 makes the program fail.*

This plug-in applies Delta Debugging to program changes, as described in Yesterday, my program worked. Today, it does not. Why?.

Available for download.

Questions?

- Work on HW4!

Sasha Laundy
@SashaLaundy

The best debugger ever made is a good night's sleep.

Translate Tweet

7:19pm · 1 Dec 2017 · Twitter Web Client

173 REPLIES 5,911 RETWEETS 14,615 LIKES