Test Suite Quality

CS 485/698: AI-Assisted SE

Today's Agenda

- Team meeting (~5 minutes)
  - Standup: how is P5 going? What else do you plan to build before the end of the semester (i.e., for P7)?
  - If your project team has two or more people, split yourselves into **offensive** and **defensive** sub-teams of approximately equal size.
    - I will stop by during the team meeting to ask
- Lecture on test suite quality metrics
- In-class activity: testing your tests

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  - Traditional answer: to show that we've done a good job testing the program
  - 2026 answer: to give our AI agents a ***fitness function*** for the test suites that we're asking them to write

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  - Repeat until some stopping condition

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  - Cheap to evaluate
- Why might we want a fitness function for an AI agent?
  - We can “put the agent in a loop” with a concrete goal and then let it run autonomously
  - Gives us a way to evaluate the quality of the agent’s work without necessarily understanding the details

Test Suite Quality Metrics

- How can we automatically measure test suite quality?
- Today we will cover two approaches:
  - **Coverage**: how much of the program's behavior have we actually checked?
  - **Adversarial**: if we intentionally seed bugs into the program, does the test suite actually detect them?

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- Most languages have one or more test frameworks that provide statement coverage instrumentation
    - e.g., Jest for JavaScript, gcov for C, Cobertura for Java

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  - Statement coverage doesn't consider whether the program got the right answer
    - Actually, it doesn't evaluate the oracle **at all**
      - Really, it measures how good your ***inputs*** are, not how good your tests are!

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      - how good your tests are!

We can address the first problem with better coverage metrics, but for the second problem we need a completely different approach

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    - Why?

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- Branch coverage gives **more confidence** than statement coverage
  - In fact, 100% branch coverage **implies** 100% line coverage
    - Why?
- However, branch coverage is "**more expensive**" in the sense that it is harder for a test suite to have high branch coverage than to have high statement coverage

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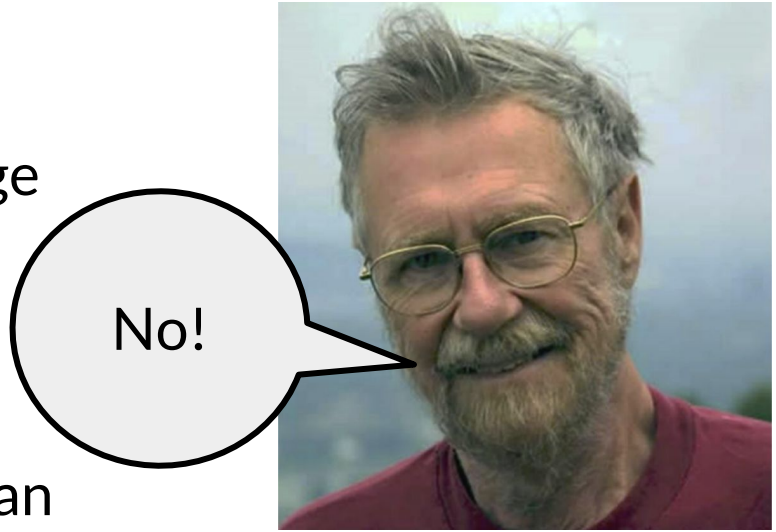

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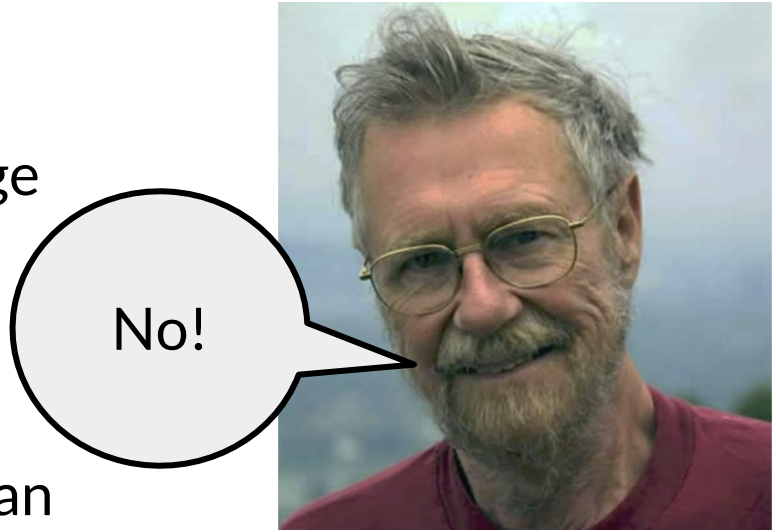

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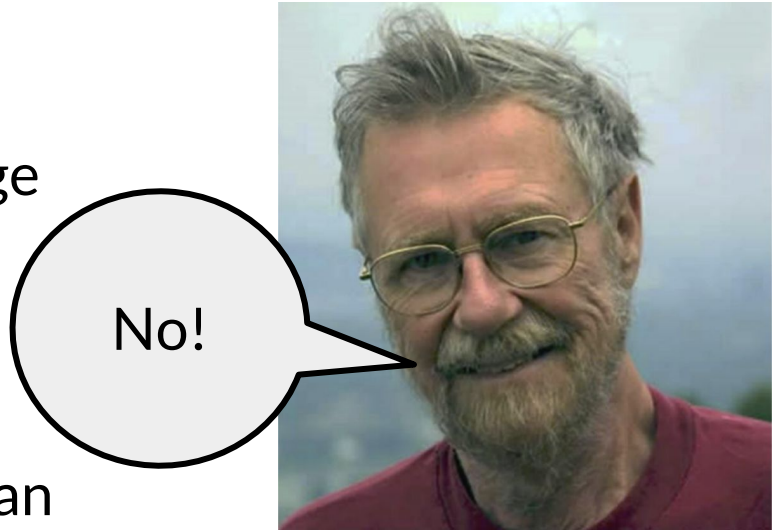

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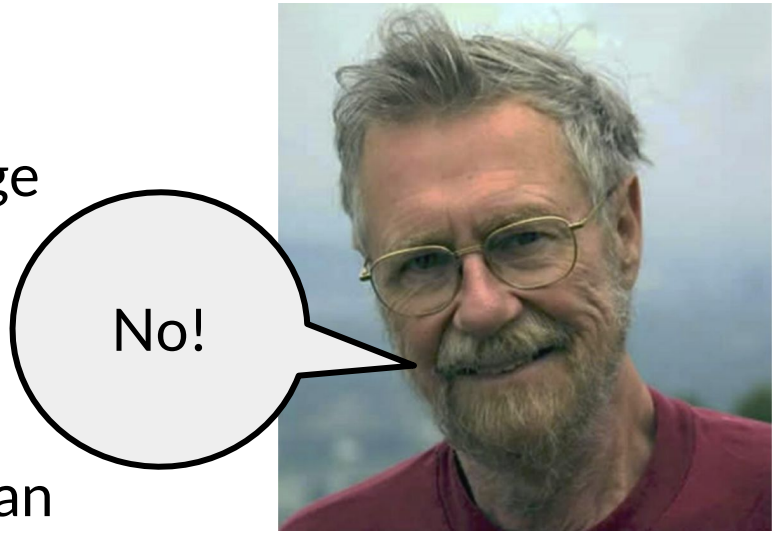

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- Can we get **finer-grained** than branch coverage?

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- **Modified Condition / Decision Coverage** (MC/DC): condition coverage plus more
    - Used in mission critical (e.g., avionics) software

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  - …and then see whether the "watchers" **actually detect** the known problems!
- In software testing, the tests are the watchers. The application of this general technique to testing is called ***mutation testing***

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- Why is this better than coverage?
  - Evaluates both coverage of inputs and **quality of oracles** implicitly: to find the seeded bug you must both reach the line and detect that something is wrong!

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- A test suite is said to ***kill*** (or ***detect***, or ***reveal***) a mutant if the mutant fails a test that the original passes.
- Mutation testing of a test suite proceeds by making a number of mutants and measuring the fraction of them killed by that test suite. This fraction is called the ***mutation adequacy score*** (or just ***mutation score***).
    - A test suite with a **higher score is better**.

Mutation testing: interpreting the score

- Is it a good idea to ask your LLM to try to write a test suite that achieves 100% mutation score? Why or why not?
  - ***Equivalent Mutant Problem***: semantically-equivalent mutants cannot be detected by any test suite and dilute the score
    - Checking if two programs are semantically-equivalent is **undecidable**, so this problem is not solvable in the limit
- As a result:
  - Mutation scores are not comparable across programs
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  - Defensive team is responsible for helping you set up their project
- **Mild contest**: who can find more bugs by the end of class?

Wrapup and Reminders

- P5 due Sunday