CMPT 473
Software Testing, Reliability and Security

Program Analysis Tools

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Fixing bugs is costly

Why?
Fixing bugs is costly

- The longer broken code exists, the more code depends upon it.
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• Bugs that escape into the wild have real world impact
  – Unintended car acceleration
  – Spacecraft crashes
  – Security leaks
  – ...

–...
Fixing bugs is costly

- Strategy so far:
  - Test to ensure that expected behaviors seem okay
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Why do we still have bugs?
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  - But we have seen that testing alone is a best effort process: no panacea in adequacy criteria
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- **Instead we can be proactive:**
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  - Guard against certain classes of bugs
  - Even prove that certain bugs are not present
  - Identify bad styles that may lead to bugs
How can we do this?

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  - Set of tools/techniques that allow computers to automatically reason about the behavior of programs
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  – Set of tools/techniques that allow computers to automatically reason about the behavior of programs

• Push the burden of understanding programs onto computers
  – People have trouble with repetitive, subtle behavior
  – *Computers excel at it*
For example

```c
if ((err = update(&ctx, &server)) != 0)
goto fail;
if ((err = update(&ctx, &params)) != 0)
goto fail;
goto fail;
if ((err = final(&ctx, &hashOut)) != 0)
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Why should a computer be able to find it?
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  - *Rules* can determine what is buggy or not
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**BUG:** Both branches of the if statement have the same target
Two main categories of tools

- Dynamic analysis tools
  - Run the program and reason about that single execution
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- **Dynamic analysis** tools
  - Run the program and reason about that single execution
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- **Static analysis** tools
  - Examine the source code or binary and reason about all possible executions
  - Best at identifying bugs that haven't struck yet but might in the future
Two main categories of tools

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This one is tougher....
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The halting problem strikes again....
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  – False positives – Warnings about bugs that don't actually exist
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- The results are imperfect
  - False positives – Warnings about bugs that don't actually exist
  - False negatives – Missing warnings for bugs that do exist
- Learning how to use these tools effectively can take practice
But what can they actually do?

- You've already seen the PVS-Studio examples

Was it a static or dynamic tool?
But what can they actually do?

- You've already seen the PVS-Studio examples
- Many tools are freely available:
  - *Lint
  - FindBugs
  - Clang Static Analyzer
  - ESC/Java
  - Valgrind
  - Clang Sanitizers
  - ... (and more on the course web page)
Taking a look at Valgrind

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    • Cacheigrind – performance analyses
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Does not work for Java or Python by default. Why?!
Taking a look at clang sanitizers

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    • Undefined Behavior – Just what it sounds like (which is?)
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45
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- What about the static analysis tools?
Clang static analyzer

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    - And a plug-in system for recognizing new ones.
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    - And a plug-in system for recognizing new ones.
  - Poorly organized & asserted code yields many errors
Google Error Prone

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- Older tools like FindBugs are great if they work for you
  - Broader classes of bugs handled
  - Can analyze all dependencies of a project using static analysis
  - Not as well maintained anymore
Dealing With False Information

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- False *positives* can waste developer time
  - Like chasing ghosts through the source code

You must eventually figure out that the ghost isn't real
Dealing With False Information

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  - Want to determine whether warnings are real

This takes a lot of work & happens every time. Can we do better?
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Blacklisting & suppression allows us to “remember” false positives & prevent them in the future....

[DEMO]
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• In contrast, we can try to use verification to prove the absence of (certain types of) bugs.

Have you seen / heard of such tools before?
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Any ideas?
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- Why didn't we just do this from the beginning?
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  - Historically more complex → more overhead
  - Still approximate, at some level (time, space, ...)
- But they are getting better!
  Used extensively in safety critical systems.
- They'll still miss bugs in the end