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Lessons Learned in Static Analysis Tool Evaluation

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Overview

- Lessons learned in the evaluation of five (5) commercially available static analysis tools
- Topics
  - Licensing
  - Performance Measurement
  - Limitations of Test Cases
  - Flaw Reporting
  - Tool Output
  - Tool Tuning
  - Tool Suites
  - Summary

Licensing

- Licensing schemes vary among vendors and have very little in common
  - Terminology ambiguity (or the same term applied differently by vendors)
    - Lines of Code (LOC)
    - Codebase
- Impacts
  - Return on investment is impacted based on usage
    - Secondary releases of code can be impacted by a cumulative LOC count
  - Restrictions on access to output data tied to license scheme
- Current license schemes better suited for Software (Sw) Developers vs. Sw Auditors (third party evaluators)

Performance Measurement

- A consistent set of criteria is required for measuring tool performance
  - A true positive (TP) is a flaw/weakness identified by a tool that is proven to be an actual flaw/weakness
  - A false positive (FP) is a flaw/weakness identified by a tool that is proven not to be an actual flaw/weakness
  - A false negative (FN) is a known flaw/weakness that the tool did not identify
    - Determining FN rates is problematic as it requires a thorough knowledge or annotation of the code
    - The lack of an accurate FN count makes determining the accuracy of the tools problematic

Limitations of Test Cases

- Results very sensitive to test case selection
  - Tools perform differently with different languages
    - Multi-language data set use is desired
  - Flaws are grouped at a high level (flaw type)
    - Many distinct flaws are categorized as buffer overflow
    - Need to cover the detail of each flaw types
  - Complicating factors include:
    - Read vs. write, scope, indirection, control flow
    - Natural vs. Seeded flaws
    - Scalability test difficulty

Limitations of Test Cases (2)

Natural Code

- Exhibits complicated paths
- Employs real data structs
- Uses advanced techniques
- Can stress scalability
- Exhibits idioms
- Unknown design intent
- Unknown # of real flaws
- Hard to automate analysis

Seeded Code

- Flaw content (mostly) known
- Flaw independence
- Result equivalence easier to determine
- Auto generation/testing
- Very limited in complexity
- Flaw frequency distribution does not mirror real world

Limitations of Test Cases (3)

- Many programs generate code during build
  - Code is not always generated in an easy to follow style (complicates review)
  - Code base is usually very robust
  - Code base may contain dead or useless code
  - Some tools will not analyze generated code
- Causes problems:
  - One TP or FP can appear as many
  - Unusual code structure can cause lots of FPs

Flaw Reporting

- Standard formats w/incomplete data
- Level of detail provided varies
  - Some tools provided flaw source, line #, and trace back links, and examples etc.; others are limited
- Trend analysis varied from non-existing to excellent
- Different levels of checkers granularity
- No application programming interface (API) to audit results or access to results data base

Flaw Reporting (2)

```
184    fprintf(f, uri);
185    fprintf(f, "\r\n");
186    for (i = 0; i < nh; ++i)
187          fprintf(f, h[i]);
```

Line 184 was correctly identified as containing a Format String vulnerability. The variable "uri" in this program is user controllable and is passed unchecked to the "format" parameter of "fprintf".

Line 187 was identified as a Tainted Data/Unvalidated User Input vulnerability. It is correct that the data contained in "h[i]" is unchecked user supplied data, however, like line 184, this is also passed to the "format" parameter of "fprintf". This issue is more a Format String vulnerability than it is a Tainted Data issue.

Tool Output

- Tools vary in the types of flaws they detect
- Certain checkers tended to produce a large number of FPs (noise generators)
  - These need to be identified
  - Difficult without prior knowledge
- Manual analysis – Manually inspect the flaw to determine validity
  - Open to human interpretation
  - Experienced human auditor should always make better judgment than tool
  - Time consuming
- So how do you make a somewhat "objective" comparison of tool performance?

Tool Output (2)

- Objective: Identify 25 flaws types that were detected by all 5 tools
  - Only 3 flaw types were detected by all 5 tools
  - Only 10 flaws types were detected by 4 out of 5 tools
    - Improper Return Value Used, Buffer Overflow, Command Injection, Format String, Memory Leak, Null Pointer De-reference, Tainted Data, Time of Check to Time of Use (TOCTOU), Use After Free, Un-initialized Value
    - This set ended up being of interest to the evaluation because of coverage not because of the flaw type itself
  - There were some additional flaws covered by the tools, but the code base did not provide TP hits
- Evaluate the tools at their default and "ideal" settings
  - Reduce the "noisy" checkers

Tool Tuning

- Not all tools are tunable
  - Some allow tuning in the analysis and/or post analysis phase
- Analysis Phase
  - Enable/disable analysis engines, algorithms
  - Set thresholds, filtering of results
  - Create custom models or rules to help analysis
- Post-Analysis Phase (Review and Audit)
  - Filtering
  - Categorization
  - Prioritization

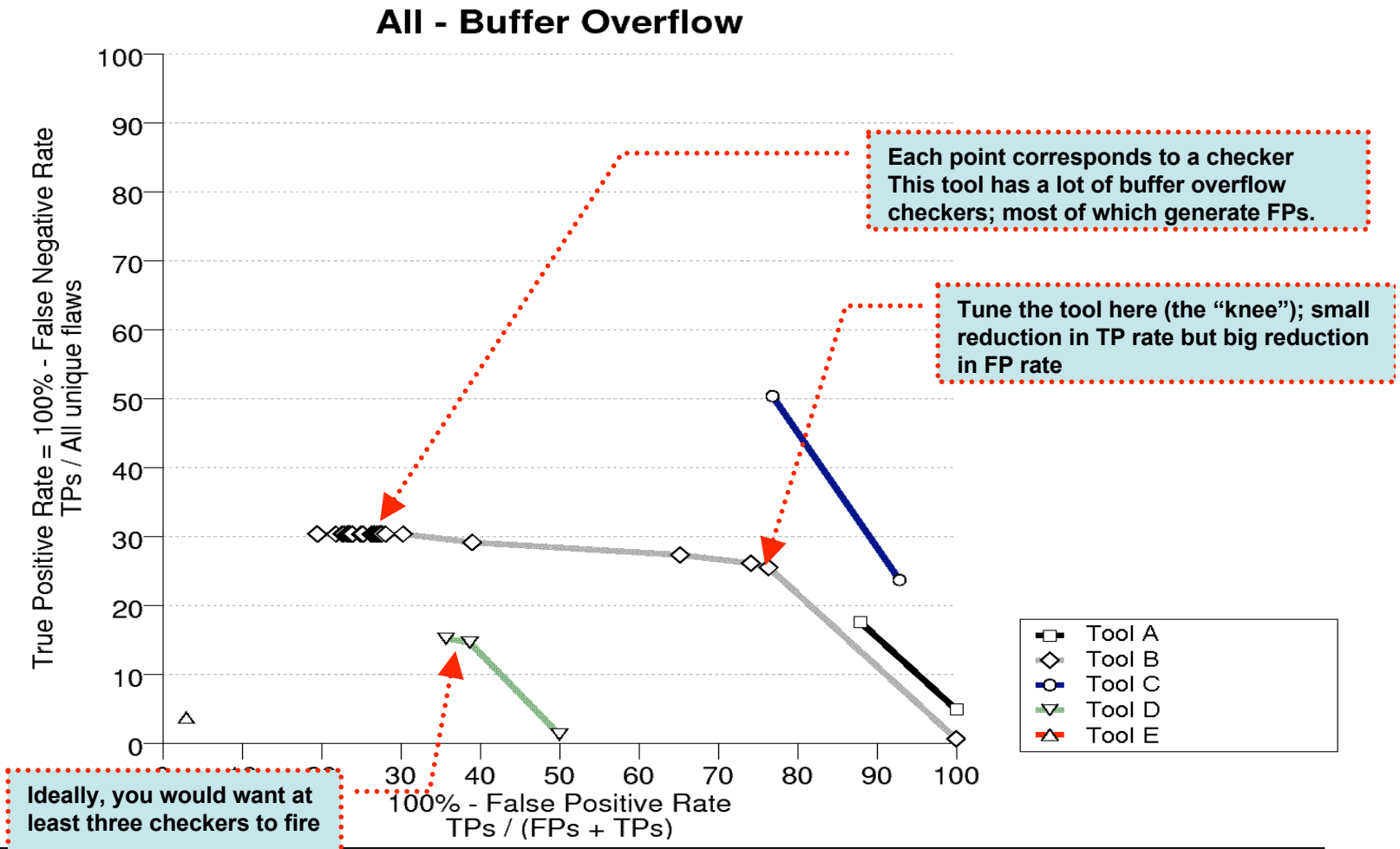
Potential loss of raw results

More manual analysis

Tool Tuning - Virtual

- Initially, requires sample code bases of known flaws
  - Sample code base consists of analyzed natural and/or seeded code
  - Can be further refined as your knowledge base of code grows
- Tuning is based upon the flaw checkers
  - Turn on ALL flaw checking options in the analysis phase and run the tool against your code samples
- For each reported issue from the tool extract:
  - source file, line number, flaw type, checker - mark it as a TP or FP
- Sort by flaw type, then artificially turn off each checker and plot how this affects the TP/FP rate
  - Shows best TP/FP tuning by flaw type
  - Allows for comparisons between tools
  - No constraints on the tool during the analysis phase

Tool Tuning - Example



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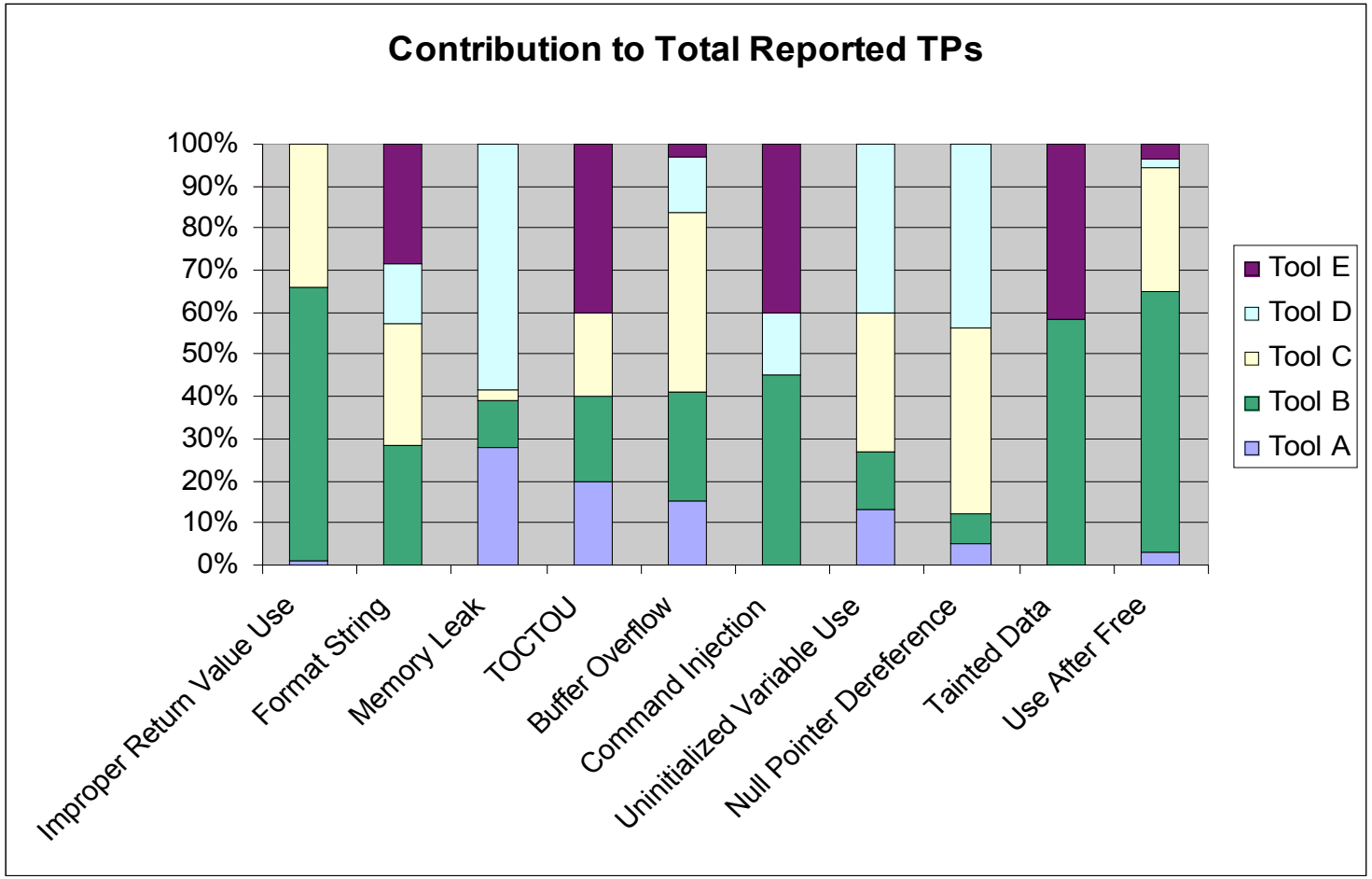
Tool Suites

- Coverage by one tool is not sufficient
  - Hard to compare tool performance based on coverage across the 10 common flaws as a whole
  - Need to look at how tools perform on a flaw by flaw basis
- Trade off between aggressive and conservative tools
  - Aggressive tools tend to report more TPs but also more FPs
  - Conservative tools report fewer FPs but increase the FN rate
- A suite of tools will provide better coverage
  - Maximized individual flaw coverage requires 2 or 3 tools

Tool Suites (2)



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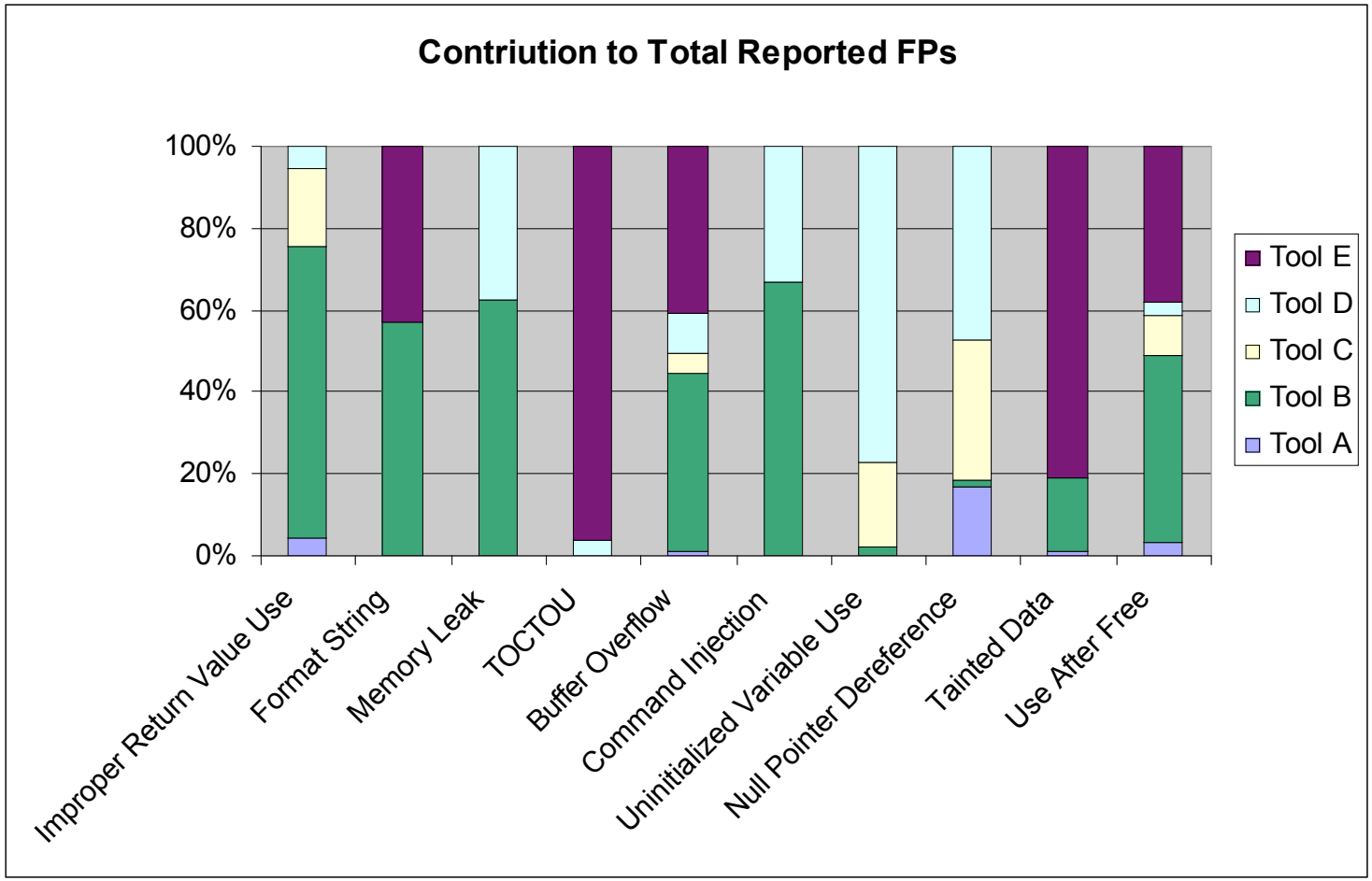
Tool Suites (3)



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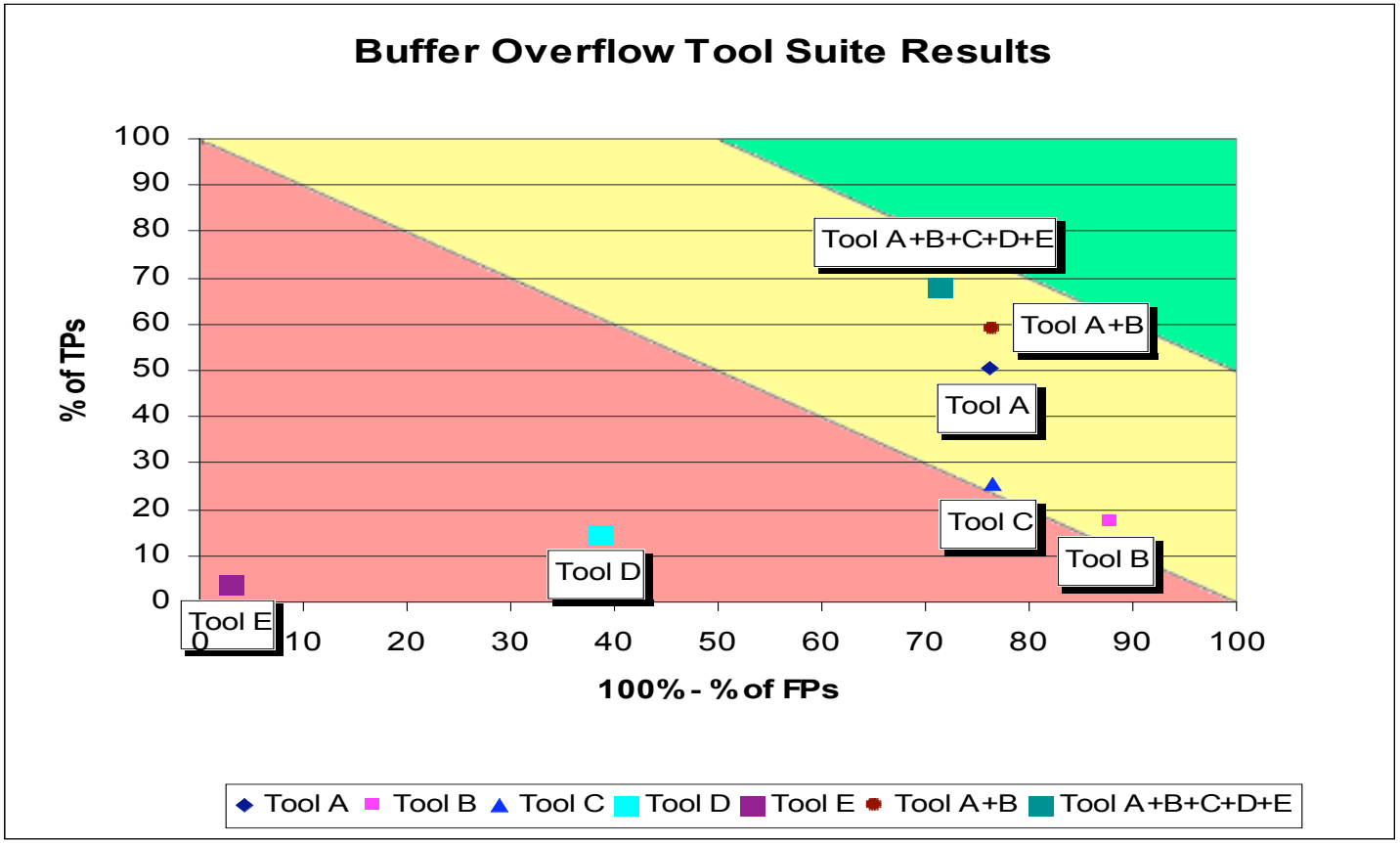
Tool Suites (4)



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Summary

- Tool overlap is not necessary in a tool suite, but overlap can increase your confidence
- Performance measurement is relative
  - Sensitive to test case selection
  - No standard
- Lack of automation
  - Analysis heavily dependent on human verification
- Virtual tuning enables you to identify individual tools strengths
- Disambiguation
  - Complex problem
  - Determining if two flaws are the same