CEN 5016: Software Engineering

Fall 2024

University of
Central Florida

Dr. Kevin Moran

Week 5 - Class 11:
Static & Dynamic Analysis

Administrivia

- *Assignment 2 Due Tomorrow*
- *SDE Project Part 1*
    - Due Tues, Sept 24th
    - Get started now!!
- *Assignment 3*
    - Will be posted tomorrow
    - Web App Deployment

Intro to Software Architecture

Why Document Architecture?

- Blueprint for the system
  - Artifact for early analysis
  - Primary carrier of quality attributes
  - Key to post-deployment maintenance and enhancement
- Documentation speaks for the architect, today and 20 years from today
  - As long as the system is built, maintained, and evolved according to its documented architecture
- Support traceability.

Views & Purposes

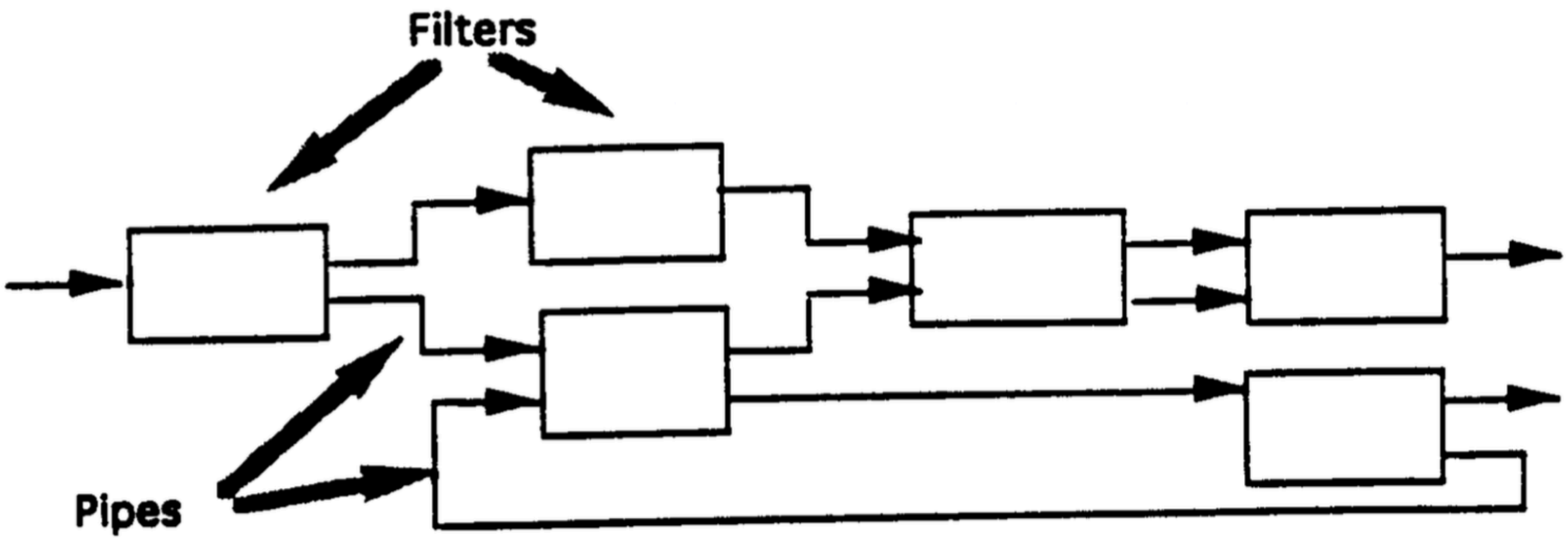
- Every view should align with a purpose
- • Views should only represent information relevant to that purpose
  - Abstract away other details
  - Annotate view to guide understanding where needed
- • Different views are suitable for different reasoning aspects (different quality goals), e.g.,
  - Performance
  - Extensibility
  - Security
  - Scalability
  - ...

Common Views in Documenting Software Architecture

- Static View
  - Modules (subsystems, structures) and their relations (dependencies, ...)
- Dynamic View
  - Components (processes, runnable entities) and connectors (messages, data flow, ...)
- Physical View (Deployment)
  - Hardware structures and their connections

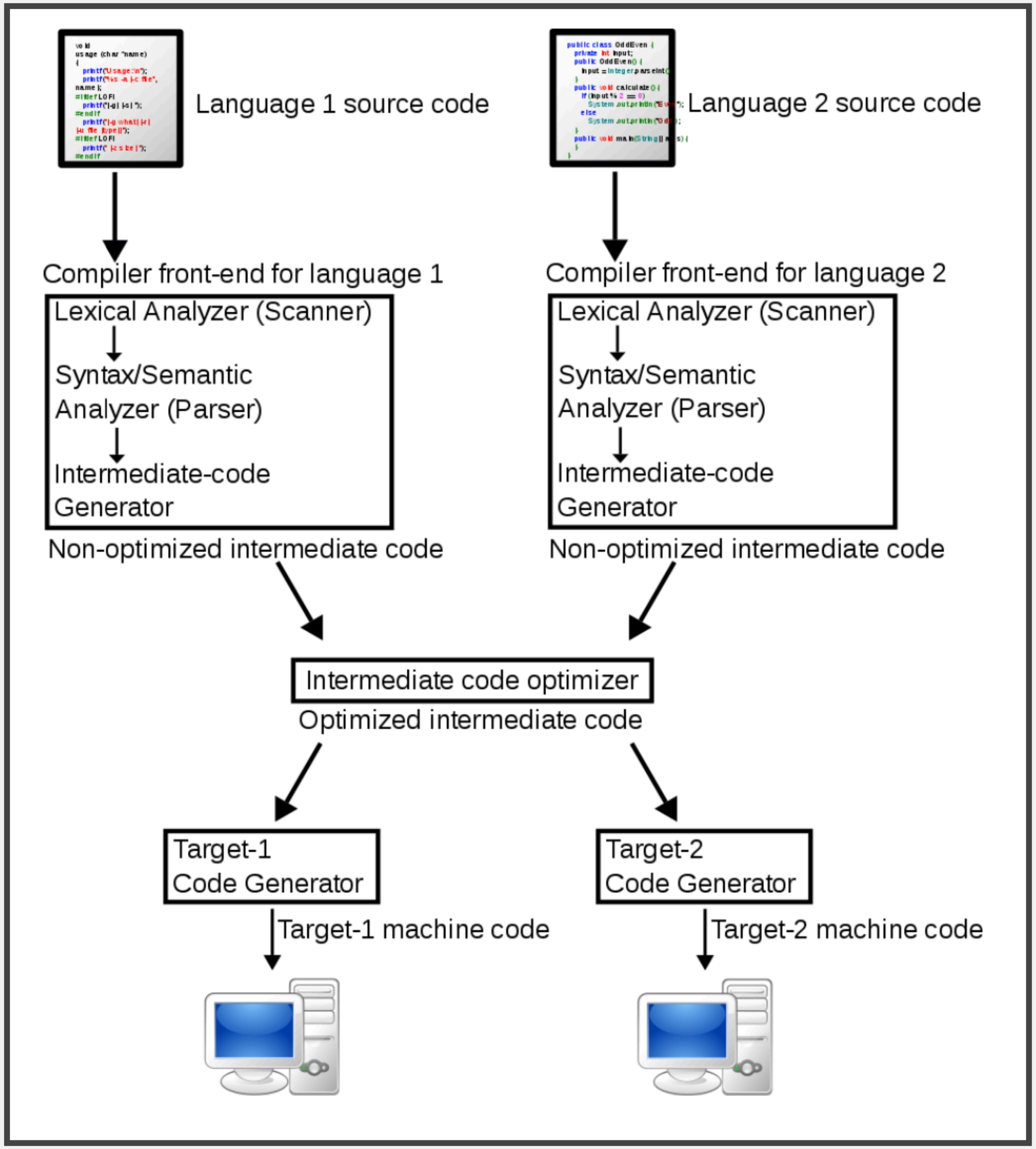
Common Software Architectures

1. Pipes & Filters


Filters
Pipes

© David Garlan and Mary Shaw, CMU/SEI-94-TR-021

Pipes & Filters Example: Compilers



Language 1 source code

Language 2 source code

Compiler front-end for language 1

Lexical Analyzer (Scanner)

Syntax/Semantic Analyzer (Parser)

Intermediate-code Generator

Non-optimized intermediate code

Compiler front-end for language 2

Lexical Analyzer (Scanner)

Syntax/Semantic Analyzer (Parser)

Intermediate-code Generator

Non-optimized intermediate code

Intermediate code optimizer

Optimized intermediate code

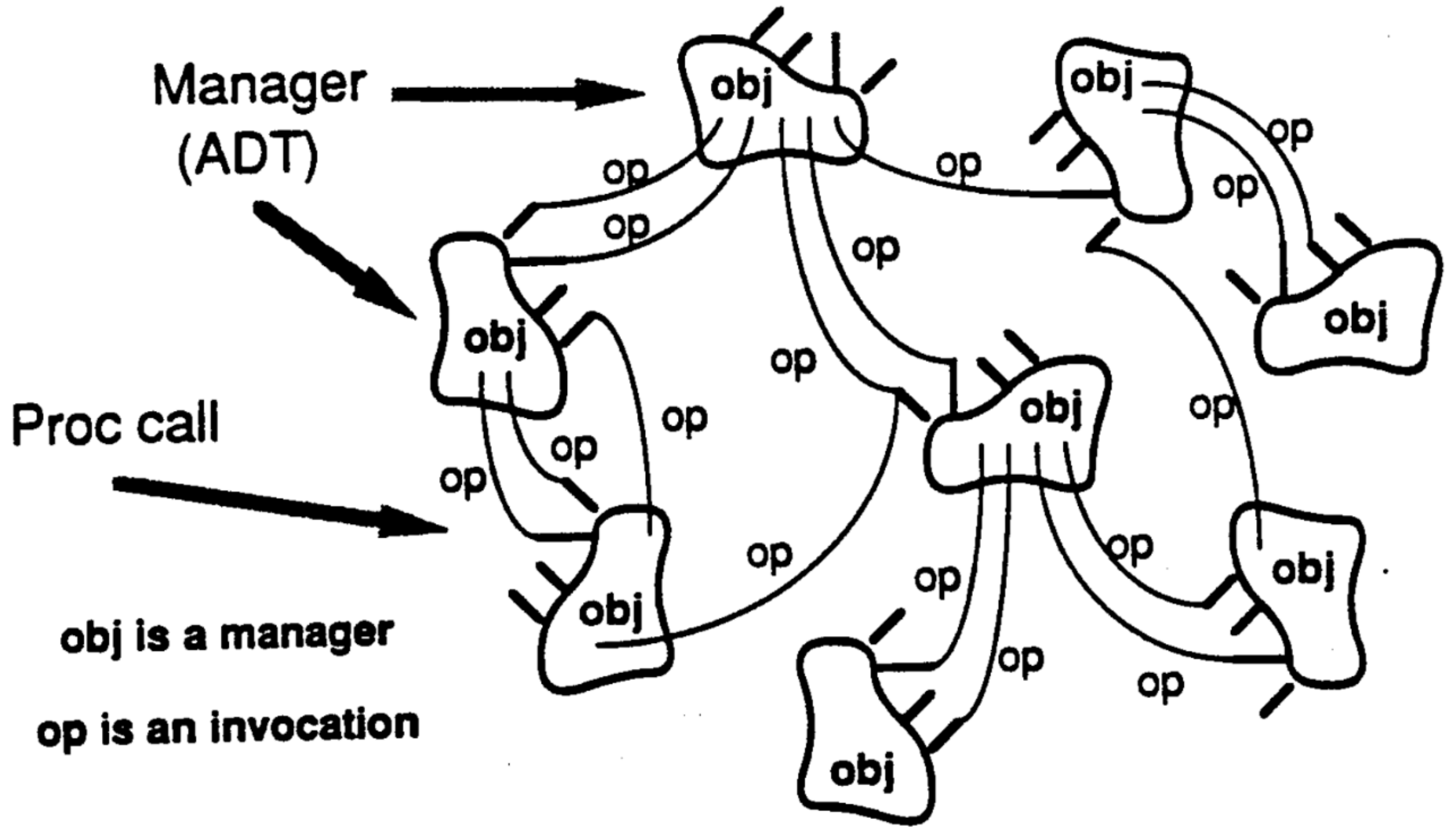
Target-1 Code Generator

Target-1 machine code

Target-2 Code Generator

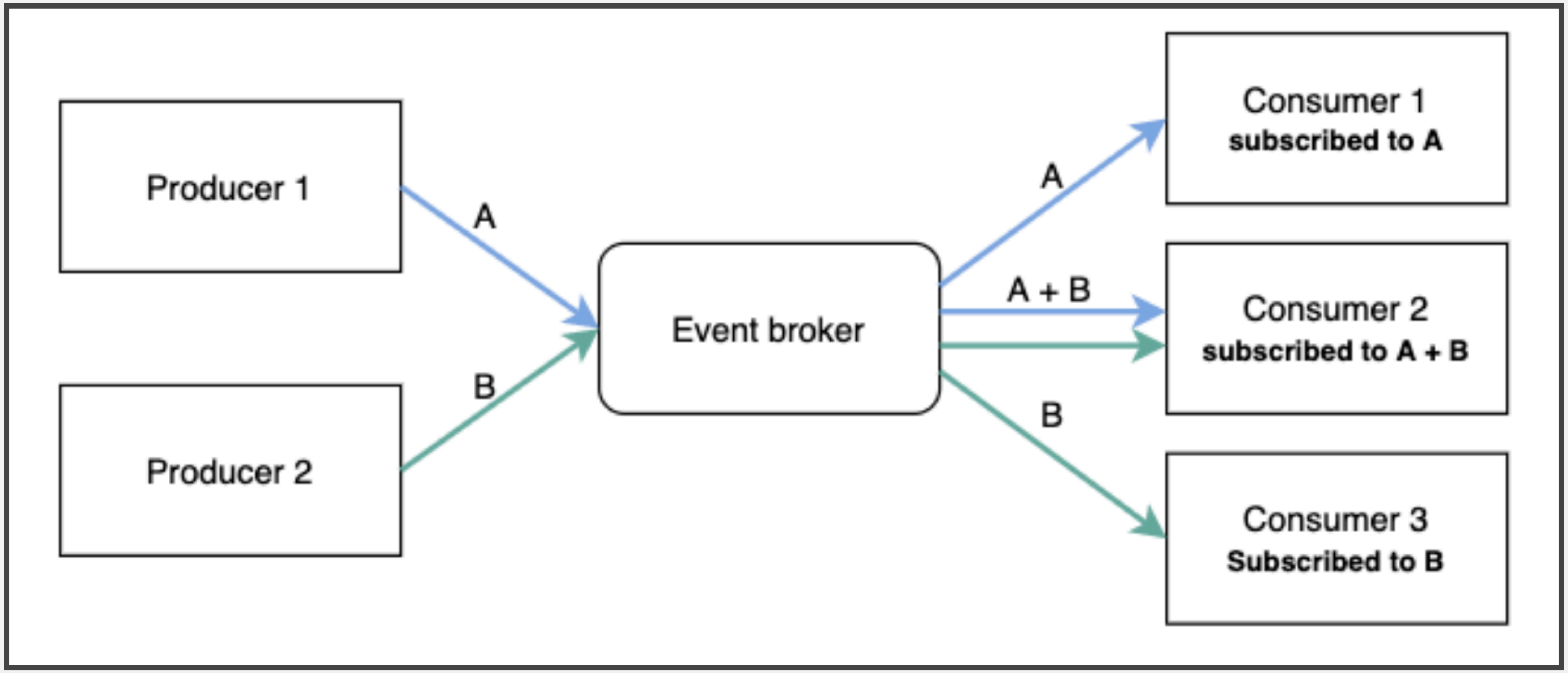
Target-2 machine code

2. Object Oriented Organization

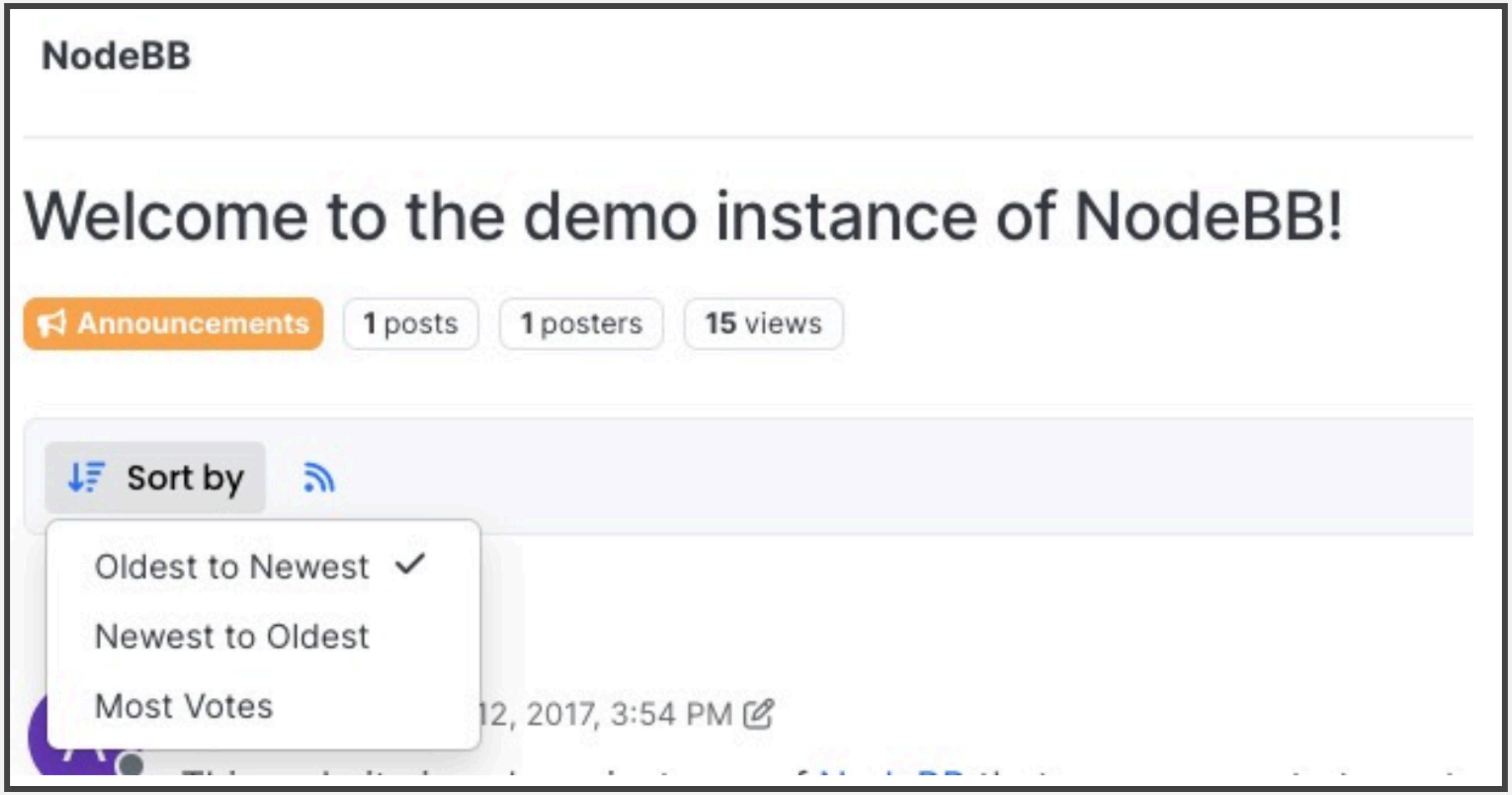

Manager
(ADT)
Proc call
obj is a manager
op is an invocation
obj
op

© David Garlan and Mary Shaw, CMU/SEI-94-TR-021

3. Event-Driven Architecture


Producer 1
Producer 2
A
B
Event broker
A
A + B
B
Consumer 1
subscribed to A
Consumer 2
subscribed to A + B
Consumer 3
Subscribed to B

Example: HTML DOM + Javascript

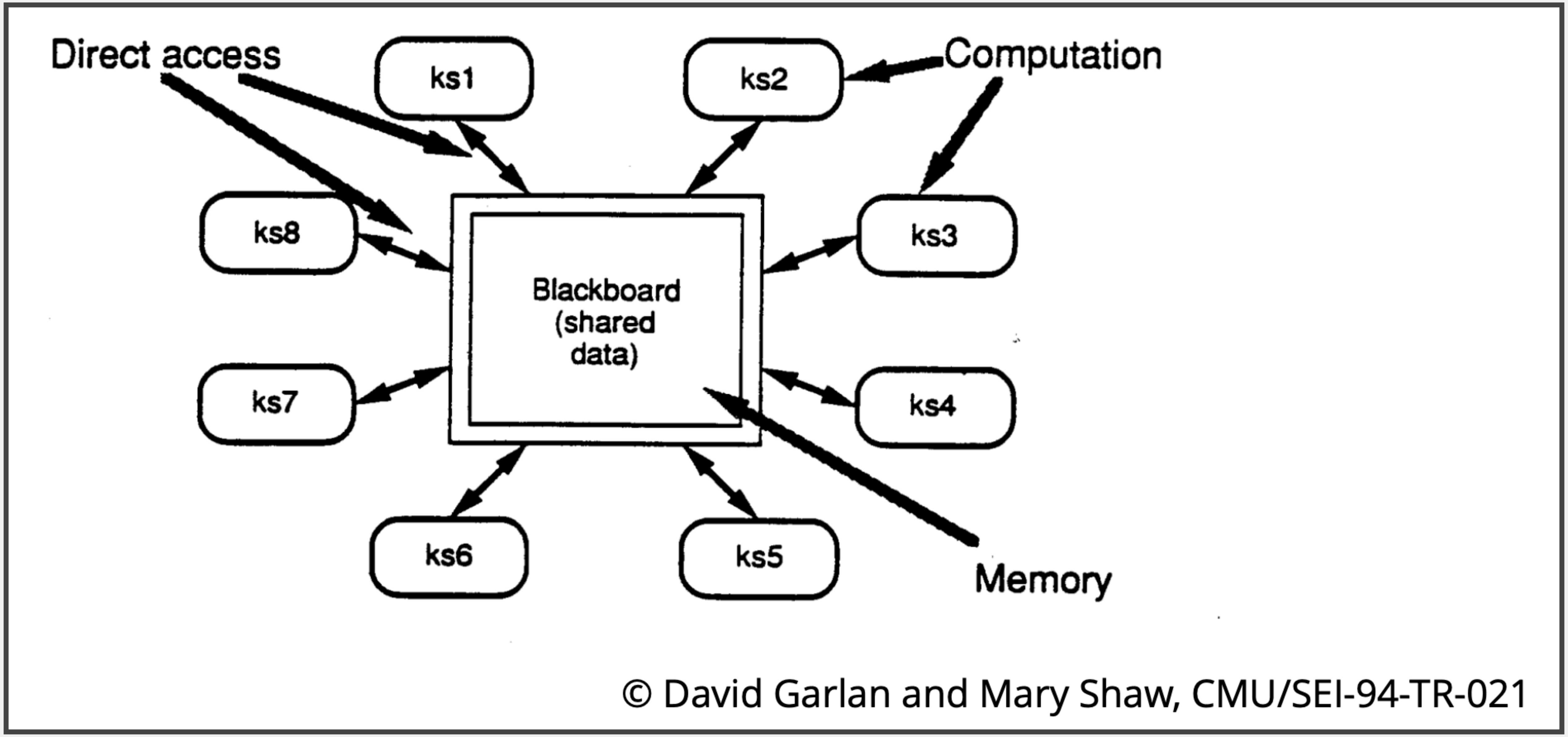


NodeBB

Welcome to the demo instance of NodeBB!

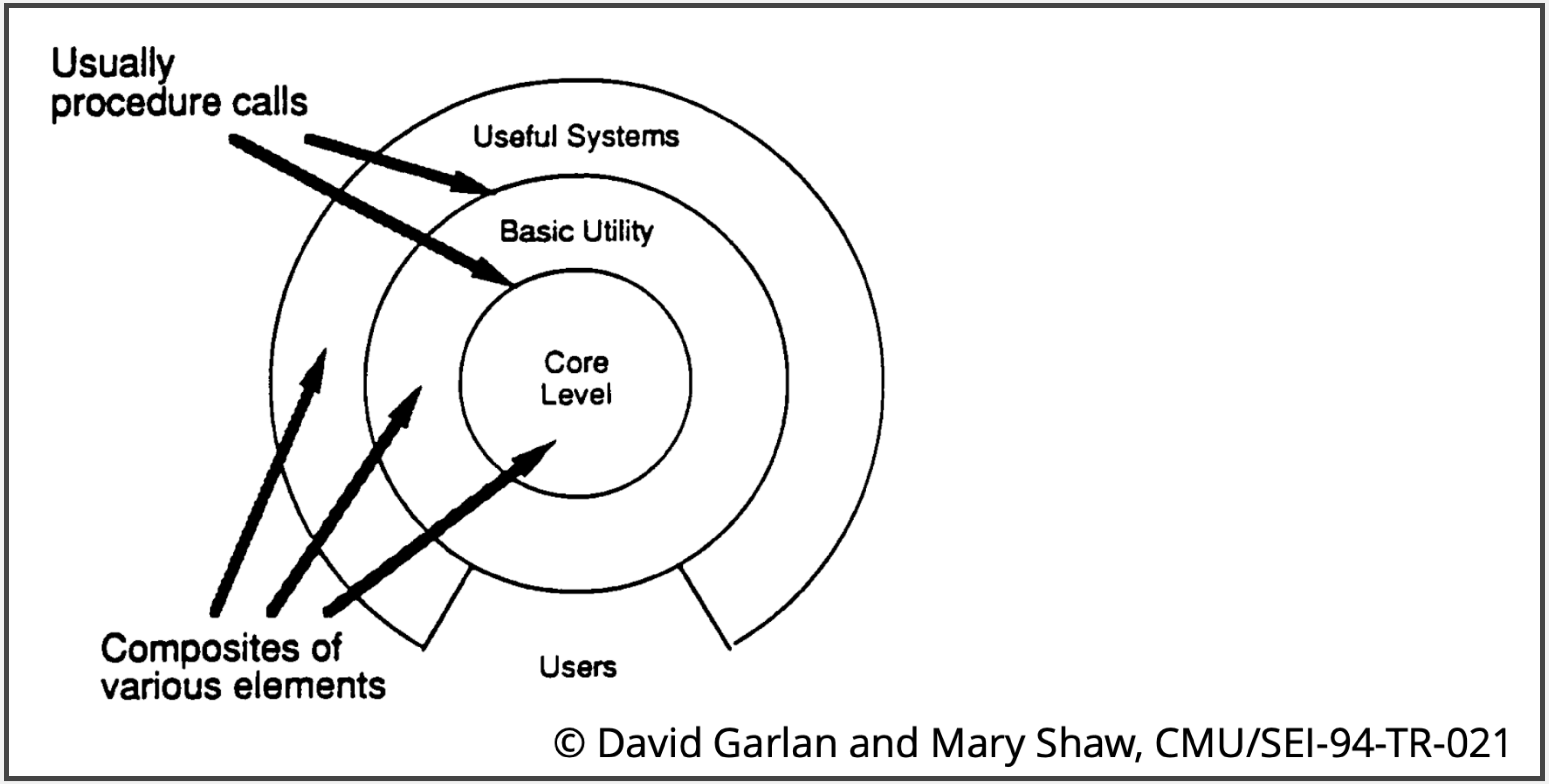
Announcements
1 posts
1 posters
15 views
Sort by
Oldest to Newest ✓
Newest to Oldest
Most Votes
12, 2017, 3:54 PM

4. Blackboard Architecture


Direct access
ks1
ks2
Computation
ks8
Blackboard (shared data)
ks3
ks7
ks4
ks6
ks5
Memory

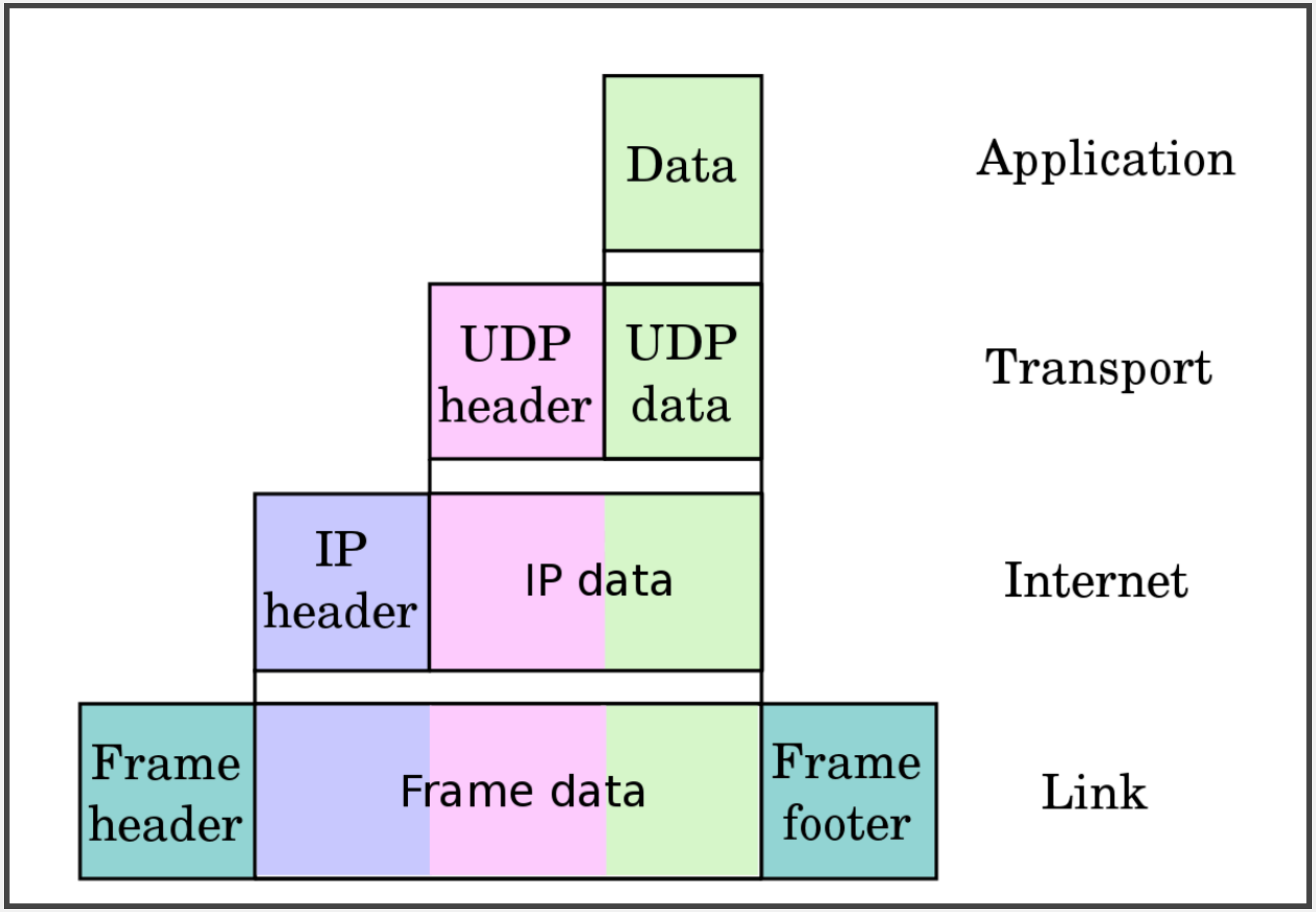
© David Garlan and Mary Shaw, CMU/SEI-94-TR-021

5. Layered Systems

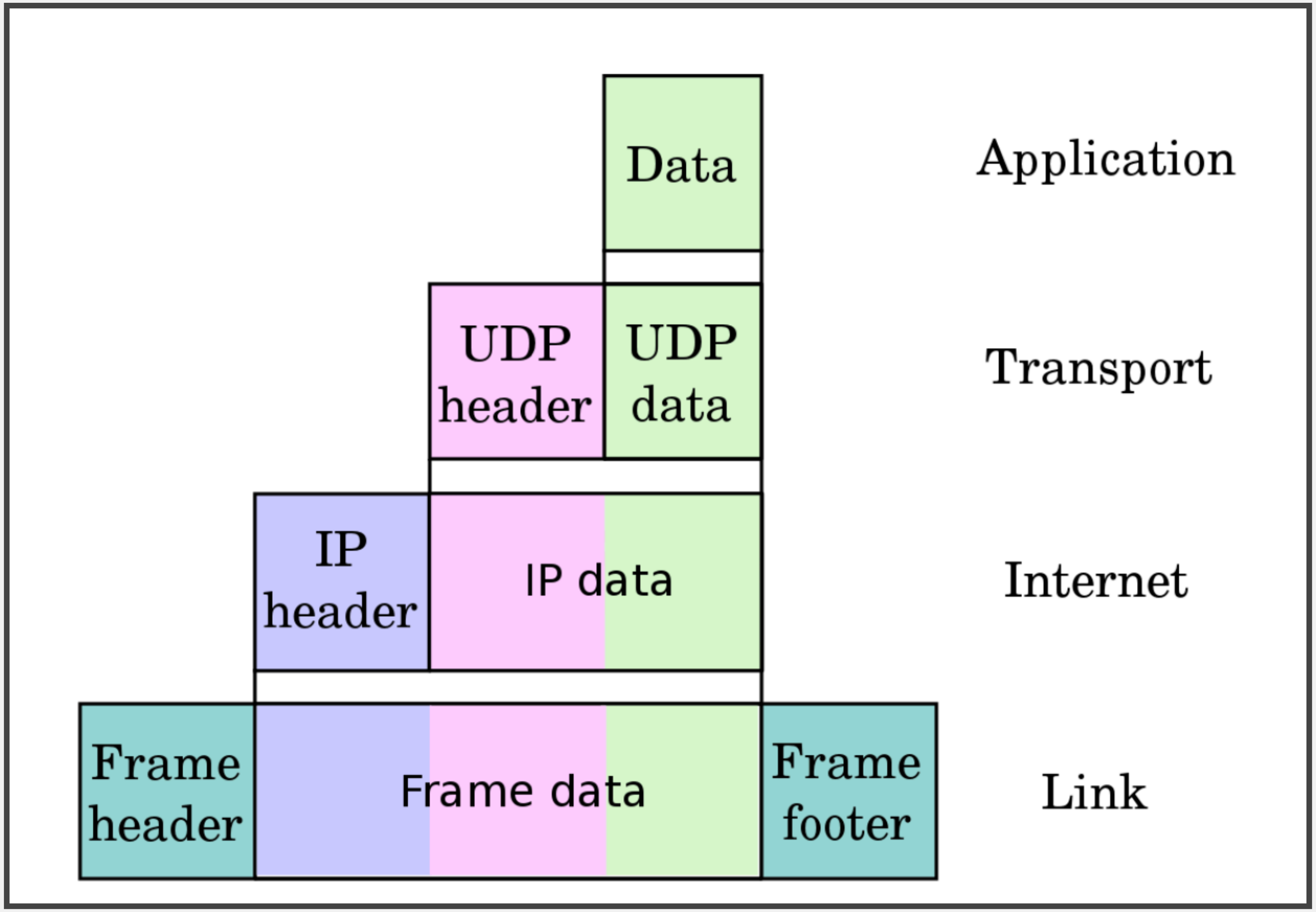

Usually procedure calls
Useful Systems
Basic Utility
Core Level
Composites of various elements
Users

© David Garlan and Mary Shaw, CMU/SEI-94-TR-021

Example Internet Protocol Suite


Data
Application
UDP header
UDP data
Transport
IP header
IP data
Internet
Frame header
Frame data
Frame footer
Link

Example Internet Protocol Suite


Data
Application
UDP header
UDP data
Transport
IP header
IP data
Internet
Frame header
Frame data
Frame footer
Link

Software QA: Static & Dynamic Analysis

Learning Goals

- Gain an understanding of the relative strengths and weaknesses of static and dynamic analysis
- Examine several popular analysis tools and understand their use cases
- Understand how analysis tools are used in large open-source software

Activity: Analyze the Python Program Statically

```
def n2s(n: int, b: int) -> str:
    if n <= 0:
        return '0'
    r = ''
    while n > 0:
        u = n % b
        if u >= 10:
            u = chr(ord('A') + u - 10)
        n = n // b
        r = str(u) + r
    return r
```

1. What are the set of data types taken by variable `u` at any point in the program?
2. Can the variable `u` be a negative number?
3. Will this function always return a value?
4. Can there ever be a division by zero?
5. Will the returned value ever contain a minus sign ‘-’?

Answer: Yes, No, Maybe

What Static Analysis Can & Cannot Do

- Type-checking is well established
  - Set of data types taken by variables at any point
  - Can be used to prevent type errors (e.g. Java) or warn about potential type errors (e.g. Python)

- Checking for problematic patterns in syntax is easy and fast
  - Is there a comparison of two Java strings using `==`?
  - Is there an array access `a[i]` without an enclosing bounds check for `i`?

- Reasoning about termination is impossible in general
  - Halting problem
- Reasoning about exact values is hard, but conservative analysis via abstraction is possible
  - Is the bounds check before `a[i]` guaranteeing that `I` is within bounds?
  - Can the divisor ever take on a zero value?
  - Could the result of a function call be `42`?
  - Will this multi-threaded program give me a deterministic result?
  - Be prepared for “MAYBE”

- Verifying some advanced properties is possible but expensive
  - CI-based static analysis usually over-approximates conservatively

Bad News: Rice's Theorem

- Every static analysis is necessarily incomplete, unsound, undecidable, or a combination thereof
- *"Any nontrivial property about the language recognized by a Turing machine is undecidable."*
- Henry Gordon Rice, 1953

Static Analysis is Well-Suited to Detecting Certain Defects

- **Security:** Buffer overruns, improperly validated input…
- **Memory safety:** Null dereference, uninitialized data…
- **Resource leaks:** Memory, OS resources…
- **API Protocols:** Device drivers; real time libraries; GUI frameworks
- **Exceptions:** Arithmetic/library/user-defined
- **Encapsulation:**
  - Accessing internal data, calling private functions…
- **Data races:**
  - Two threads access the same data without synchronization

Static Analysis Tools: Broad Classification

- Linters
  - Shallow syntax analysis for enforcing code styles and formatting
- Pattern-based bug detectors
  - Simple syntax or API-based rules for identifying common programming mistakes
- Type-annotation validators
  - Check conformance to user-defined types
  - Types can be complex (e.g., “Nullable”)
- Data-flow analysis / Abstract interpretation)
  - Deep program analysis to find complex error conditions (e.g., ” can array index be out of bounds?”)

Static Analysis Tools: Applications

- Find bugs
- Refactor code
- Keep your code stylish!
- Identify code smells
- Measure quality
- Find usability and accessibility issues
- Identify bottlenecks and improve performance

Activity: Analyze the Python Program Dynamically

```python
def n2s(n: int, b: int) -> str:
    if n <= 0:
        return '0'
    r = ''
    while n > 0:
        u = n % b
        if u >= 10:
            u = chr(ord('A') + u - 10)
        n = n // b
        r = str(u) + r
    return r
print(n2s(12, 10))
```

Answer: Yes, No, Maybe

1. What are the set of data types taken by variable `u` at any point in the program?
2. Did the variable `u` ever contain a negative number?
3. For how many loop executions did the while loop execute?
4. Was there a division by zero?
5. Did the returned value ever contain a minus sign ‘-’?

Dynamic Analysis Reasons about Program Executions

- Tells you properties of the program that were definitely observed
  - Code coverage
  - Performance profiling
  - Type profiling
  - Testing
- In practice, implemented by program instrumentation
  - Think “Automated logging”
  - Slows down execution speed by a small amount

Static Analysis vs. Dynamic Analysis

- Requires only source code
- Conservatively reasons about all possible
- Reported warnings may contain false positives
- Can report all warnings of a particular class of problems
- Advanced techniques like verification can prove certain complex properties, but rarely run in CI due to cost

- Requires successful build + test inputs
- Observes individual executions
- Reported problems are real, as observed by a witness input
- Can only report problems that are seen. Highly dependent on test inputs. Subject to false negatives
- Advanced techniques like symbolic execution can prove certain complex properties, but rarely run in CI due to cost

Static Analysis

Tools for Static Analysis

CSI

University of Maryland 18 56
FindBugs™
because it's easy

: my[py]

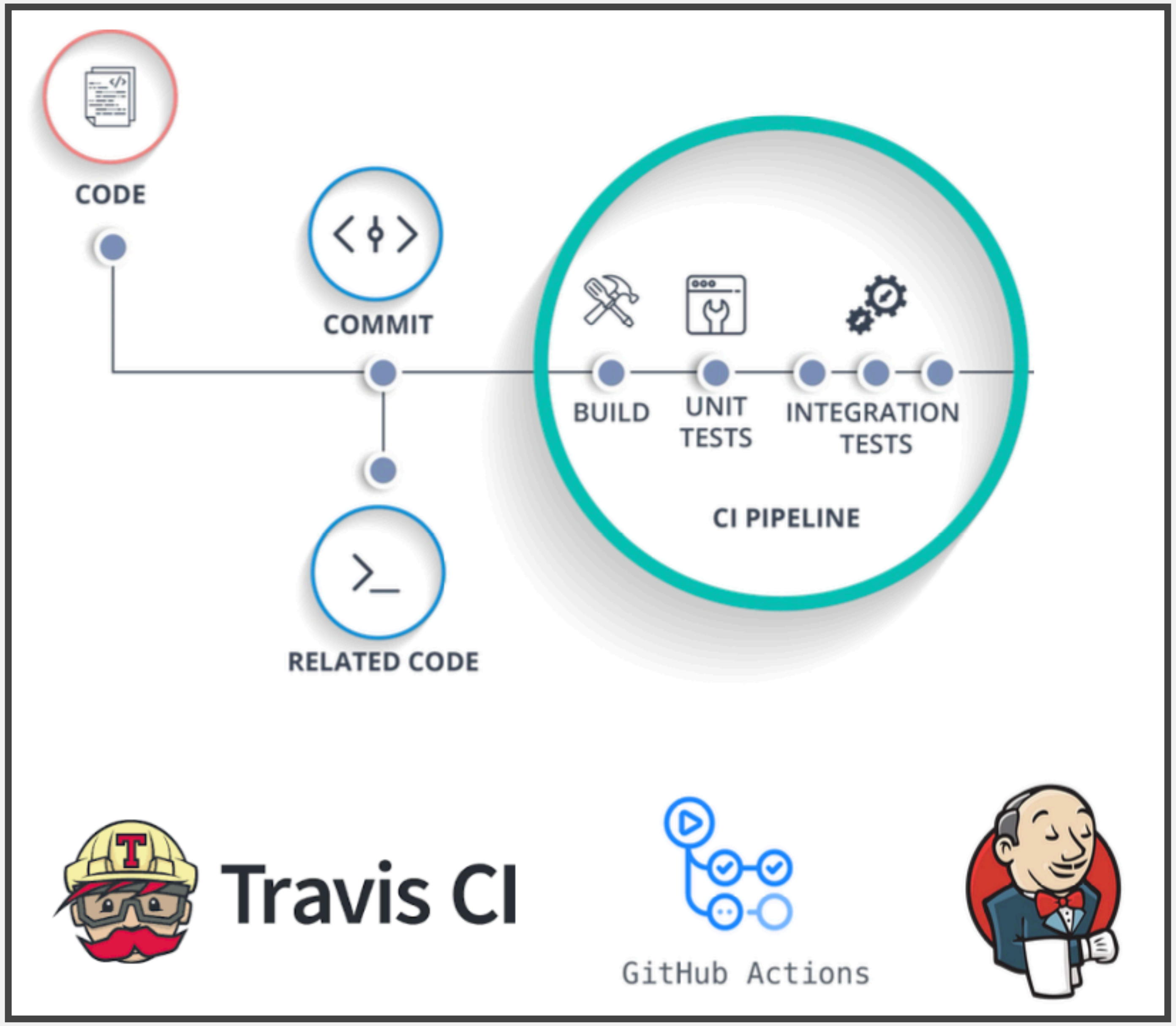
snyk

sonarqube

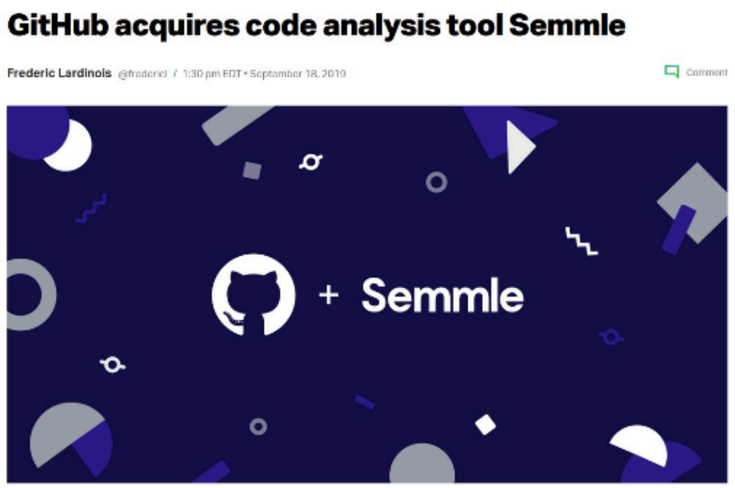
coverity®
SYNOPSYS®

squale

Static Analysis is a Key Part of CI


CODE
COMMIT
RELATED CODE
BUILD
UNIT TESTS
INTEGRATION TESTS
CI PIPELINE
Travis CI
GitHub Actions

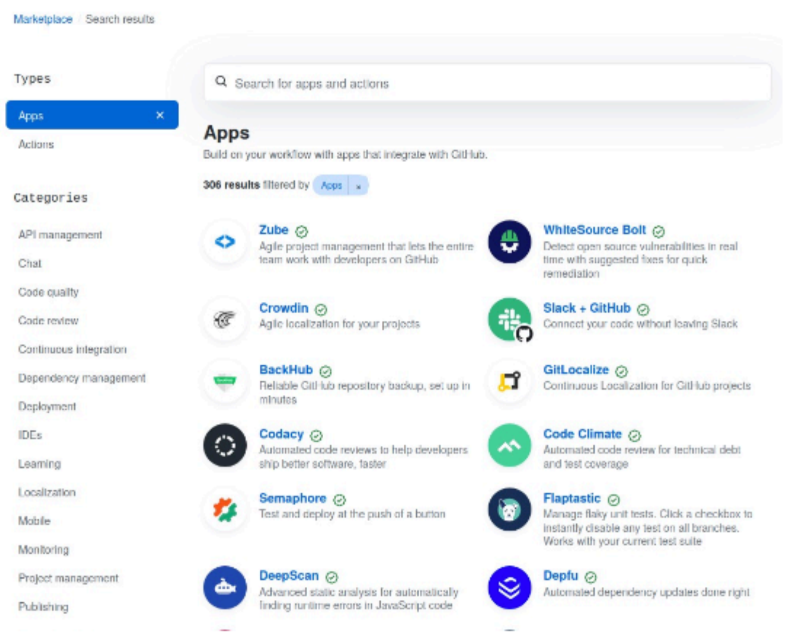
Static Analysis used to be Purely Academic…



GitHub acquires code analysis tool Semmle

Frederic Lardinois @frederic / 1:30 pm EDT • September 18, 2019

Comment
+ Semmle



Marketplace / Search results

Types
Apps ×
Actions
Categories
API management
Chat
Code quality
Code review
Continuous integration
Dependency management
Deployment
IDEs
Learning
Localization
Mobile
Monitoring
Project management
Publishing
Search for apps and actions

Apps

Build on your workflow with apps that integrate with GitHub.

306 results filtered by Apps ×

Zube – Agile project management that lets the entire team work with developers on GitHub

WhiteSource Bolt – Detect open source vulnerabilities in real time with suggested fixes for quick remediation

Crowdin – Agile localization for your projects

Slack + GitHub – Connect your code without leaving Slack

BackHub – Reliable GitHub repository backup, set up in minutes

GitLocalize – Continuous Localization for GitHub projects

Codacy – Automated code reviews to help developers ship better software, faster

Code Climate – Automated code review for technical debt and test coverage

Semaphore – Test and deploy at the push of a button

Flaptastic – Manage flaky unit tests. Click a checkbox to instantly disable any test on all branches. Works with your current test suite

DeepScan – Advanced static analysis for automatically finding runtime errors in JavaScript code

Depfu – Automated dependency updates done right

GitHub

News

Snyk Secures $150M, Snags $1B Valuation

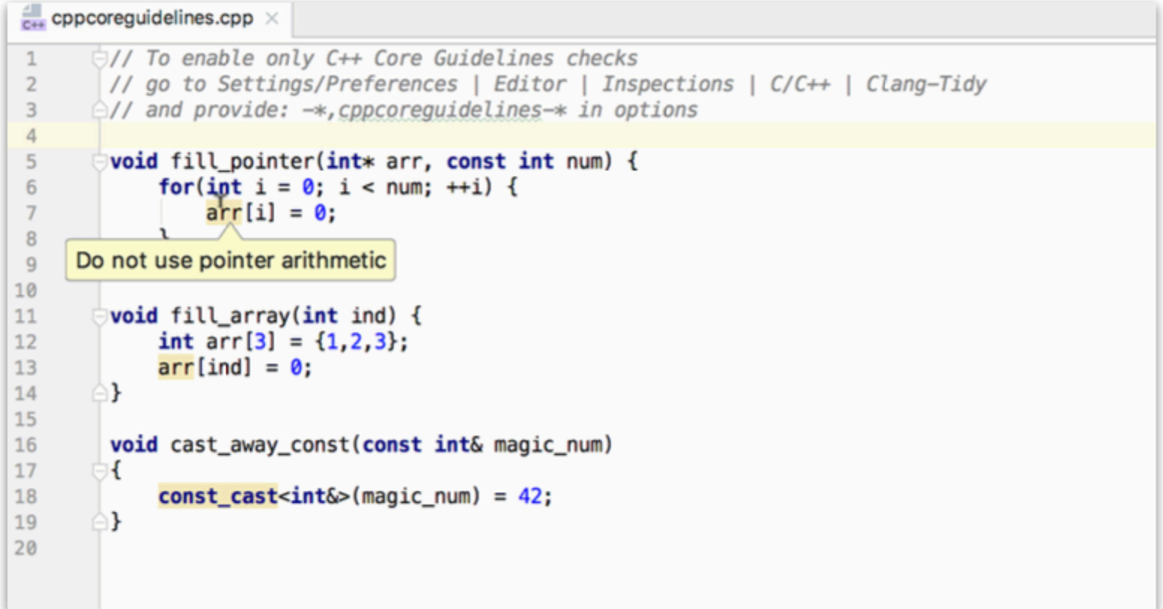
Sydney Sawaya | Associate Editor
January 21, 2020 1:12 PM

Share this article:

Snyk, a developer-focused security startup that and identifies vulnerabilities in open source applications, announced a $150 million Series C funding round today. This brings the company's total investment to $250 million alongside reports that put the company's valuation at more than $1 billion.

snyk

Static Analysis is Also Integrated into IDEs



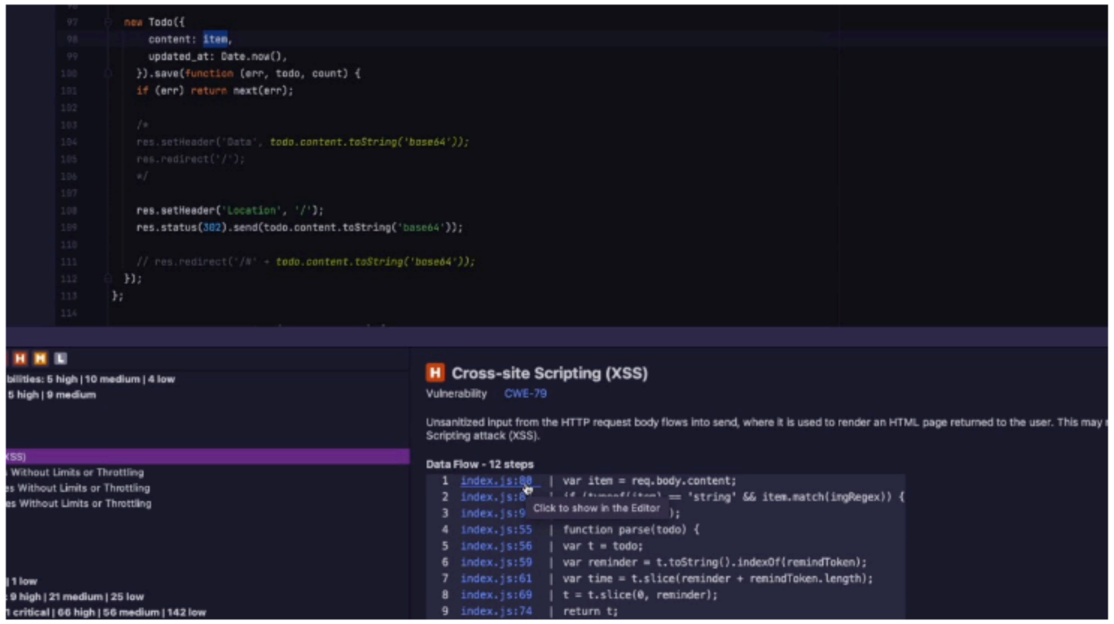
```
// To enable only C++ Core Guidelines checks
// go to Settings/Preferences | Editor | Inspections | C/C++ | Clang-Tidy
// and provide: -*,cppcoreguidelines-* in options

void fill_pointer(int* arr, const int num) {
    for(int i = 0; i < num; ++i) {
        arr[i] = 0;
    }

void fill_array(int ind) {
    int arr[3] = {1,2,3};
    arr[ind] = 0;
}

void cast_away_const(const int& magic_num)
{
    const_cast<int&>(magic_num) = 42;
}
```

Do not use pointer arithmetic



```
    new Todo({
      content: item,
      updated_at: Date.now(),
    }).save(function (err, todo, count) {
    if (err) return next(err);

    /*
    res.setHeader('Data', todo.content.toString('base64'));
    res.redirect('/');
    */

    res.setHeader('Location', '/');
    res.status(302).send(todo.content.toString('base64'));

    // res.redirect('/#' + todo.content.toString('base64'));
  });
};
```

bilities: 5 high | 10 medium | 4 low
5 high | 9 medium

SS)
Without Limits or Throttling
es Without Limits or Throttling
es Without Limits or Throttling

| 1 low
9 high | 21 medium | 25 low
1 critical | 66 high | 56 medium | 142 low

H Cross-site Scripting (XSS)

Vulnerability CWE-79

Unsanitized input from the HTTP request body flows into send, where it is used to render an HTML page returned to the user. This may
Scripting attack (XSS).

Data Flow - 12 steps

```
1  index.js:88  | var item = req.body.content;
2  index.js:8   |                     == 'string' && item.match(ingRegex)) {
3  index.js:9                                  );
4  index.js:55  | function parse(todo) {
5  index.js:56  | var t = todo;
6  index.js:59  | var reminder = t.toString().indexOf(remindToken);
7  index.js:61  | var time = t.slice(reminder + remindToken.length);
8  index.js:69  | t = t.slice(0, reminder);
9  index.js:74  | return t;
```

What Makes a Good Static Analysis Tool?

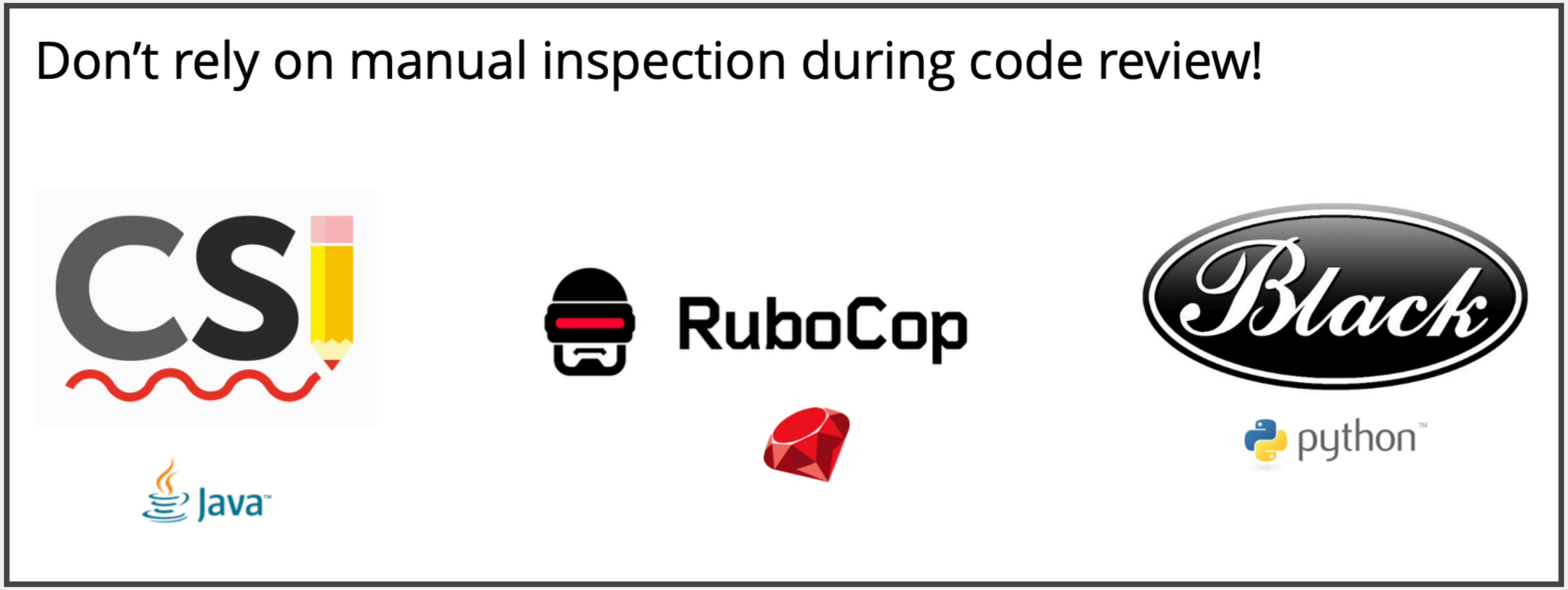
- Static analysis should be fast
    - Don’t hold up development velocity
    - This becomes more important as code scales
- Static analysis should report few false positives
    - Otherwise developers will start to ignore warnings and alerts, and quality will decline
- Static analysis should be continuous
    - Should be part of your continuous integration pipeline
    - Diff-based analysis is even better -- don’t analyse the entire codebase; just the changes
- Static analysis should be informative
    - Messages that help the developer to quickly locate and address the issue
    - Ideally, it should suggest or automatically apply fixes

(1) Linters

- Cheap, fast, and lightweight static source analysis

Use Linters to Enforce Style Guidelines

- Don’t rely on manual inspection during code review!



Don’t rely on manual inspection during code review!

CS
Java
RuboCop
Black
python

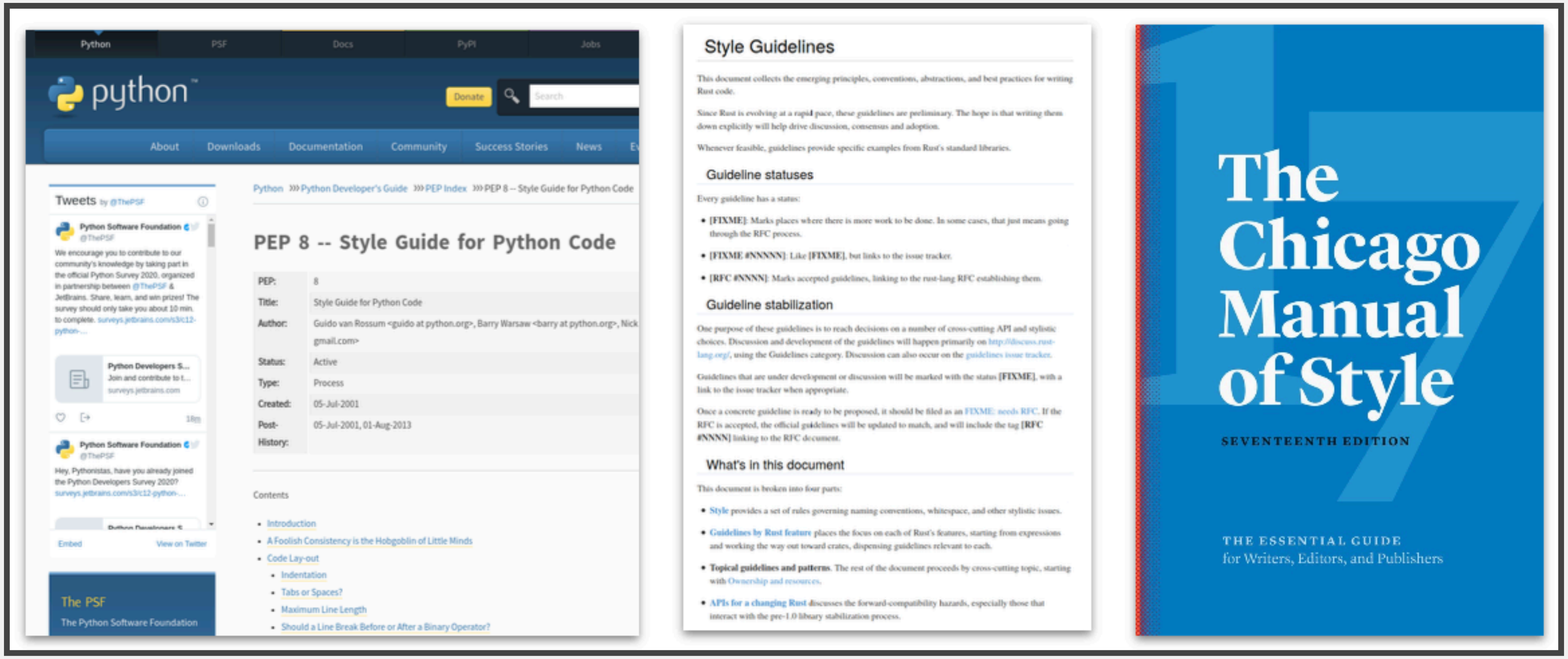
Linters Use Very “Shallow” Static Analysis

- Ensure proper indentation
- Naming convention
- Line sizes
- Class nesting
- Documenting public functions
- Parenthesis around expressions
- What else?

Use Linters to Improve Maintainability

- Why? We spend more time reading code than writing it.
    - Various estimates of the exact %, some as high as 80%
- Code is ownership is usually shared
- The original owner of some code may move on
- Code conventions make it easier for other developers to quickly understand your code

UseStyle Guidelines to Facilitate Communication



Python »» Python Developer's Guide »» PEP Index »» PEP 8 -- Style Guide for Python Code

PEP 8 -- Style Guide for Python Code

PEP:	8
Title:	Style Guide for Python Code
Author:	Guido van Rossum <guido at python.org>, Barry Warsaw <barry at python.org>, Nick gmail.com>
Status:	Active
Type:	Process
Created:	05-Jul-2001
Post-History:	05-Jul-2001, 01-Aug-2013

Contents

- Introduction
- A Foolish Consistency is the Hobgoblin of Little Minds
- Code Lay-out
  - Indentation
  - Tabs or Spaces?
  - Maximum Line Length
  - Should a Line Break Before or After a Binary Operator?

Tweets by @ThePSF

Python Software Foundation @ThePSF

We encourage you to contribute to our community's knowledge by taking part in the official Python Survey 2020, organized in partnership between @ThePSF & JetBrains. Share, learn, and win prizes! The survey should only take you about 10 min. to complete. surveys.jetbrains.com/s3/c12-python-...

Python Developers S...
Join and contribute to t...
surveys.jetbrains.com

18m

Python Software Foundation @ThePSF

Hey, Pythonistas, have you already joined the Python Developers Survey 2020? surveys.jetbrains.com/s3/c12-python-...

Style Guidelines

This document collects the emerging principles, conventions, abstractions, and best practices for writing Rust code.

Since Rust is evolving at a rapid pace, these guidelines are preliminary. The hope is that writing them down explicitly will help drive discussion, consensus and adoption.

Whenever feasible, guidelines provide specific examples from Rust's standard libraries.

Guideline statuses

Every guideline has a status:

- **[FIXME]**: Marks places where there is more work to be done. In some cases, that just means going through the RFC process.
- **[FIXME #NNNNN]**: Like **[FIXME]**, but links to the issue tracker.
- **[RFC #NNNN]**: Marks accepted guidelines, linking to the rust-lang RFC establishing them.

Guideline stabilization

One purpose of these guidelines is to reach decisions on a number of cross-cutting API and stylistic choices. Discussion and development of the guidelines will happen primarily on http://discuss.rust-lang.org/, using the Guidelines category. Discussion can also occur on the guidelines issue tracker.

Guidelines that are under development or discussion will be marked with the status **[FIXME]**, with a link to the issue tracker when appropriate.

Once a concrete guideline is ready to be proposed, it should be filed as an FIXME: needs RFC. If the RFC is accepted, the official guidelines will be updated to match, and will include the tag **[RFC #NNNN]** linking to the RFC document.

What's in this document

This document is broken into four parts:

- **Style** provides a set of rules governing naming conventions, whitespace, and other stylistic issues.
- **Guidelines by Rust feature** places the focus on each of Rust's features, starting from expressions and working the way out toward crates, dispensing guidelines relevant to each.
- **Topical guidelines and patterns**. The rest of the document proceeds by cross-cutting topic, starting with Ownership and resources.
- **APIs for a changing Rust** discusses the forward-compatibility hazards, especially those that interact with the pre-1.0 library stabilization process.

The Chicago Manual of Style
SEVENTEENTH EDITION
THE ESSENTIAL GUIDE
for Writers, Editors, and Publishers

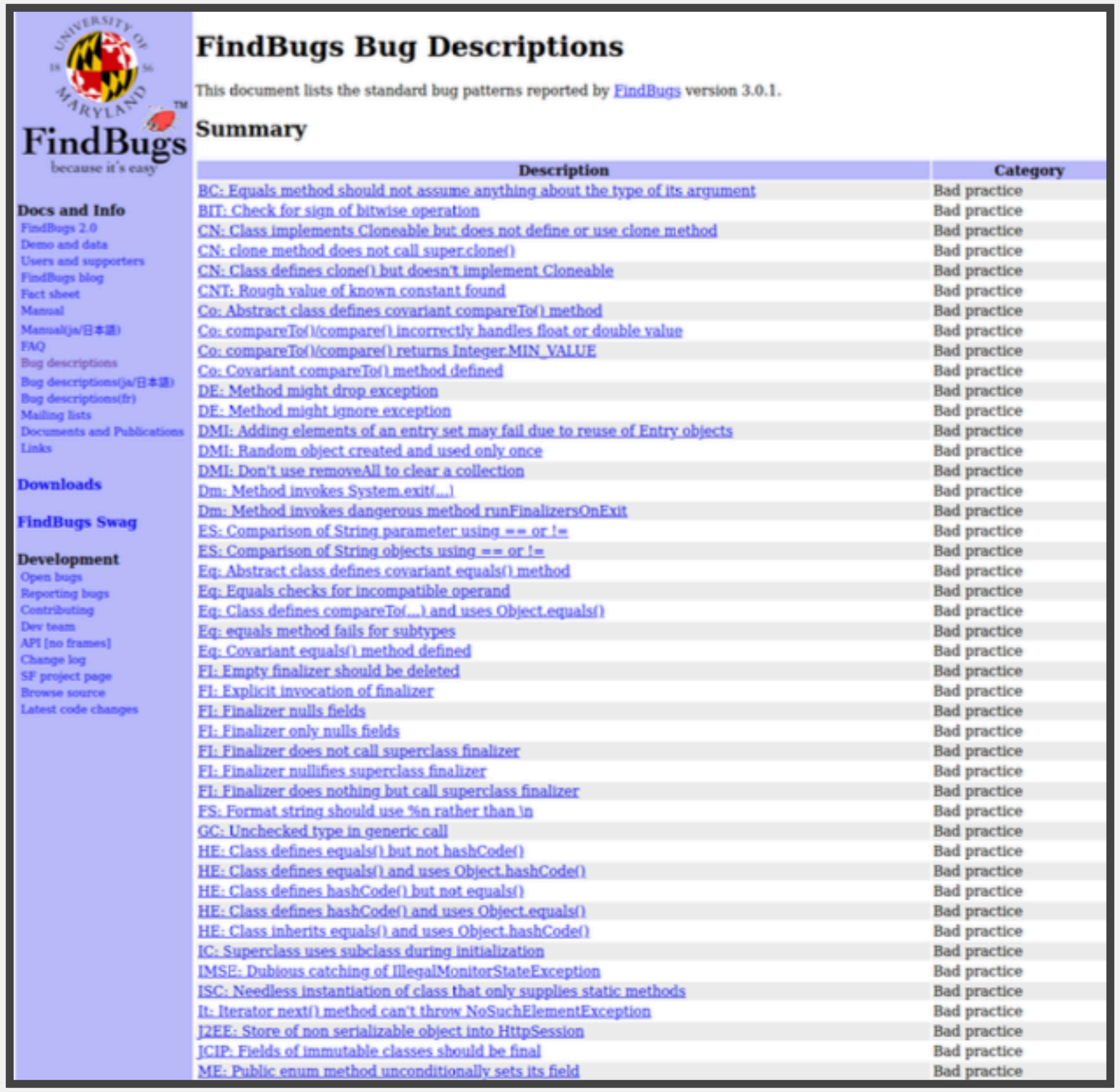
- Guidelines are inherently opinionated, but consistency is the important point. Agree to a set of conventions and stick to them.

Take Home Message: Style is an Easy Way to Improve Readability!

- Everyone has their own opinion (e.g., tabs vs. spaces)
- Agree to a convention and stick to it
  - Use continuous integration to enforce it
- Use automated tools to fix issues in existing code

(2) - Pattern-based Static Analysis Tools

- Bad Practice
- Correctness
- Performance
- Internationalization
- Malicious Code
- Multithreaded Correctness
- Security
- Dodgy Code



FindBugs™
because it's easy

Docs and Info
- FindBugs 2.0
- Demo and data
- Users and supporters
- FindBugs blog
- Fact sheet
- Manual
- Manual(ja/日本語)
- FAQ
- Bug descriptions
- Bug descriptions(ja/日本語)
- Bug descriptions(fr)
- Mailing lists
- Documents and Publications
- Links

Downloads

FindBugs Swag

Development
- Open bugs
- Reporting bugs
- Contributing
- Dev team
- API [no frames]
- Change log
- SF project page
- Browse source
- Latest code changes

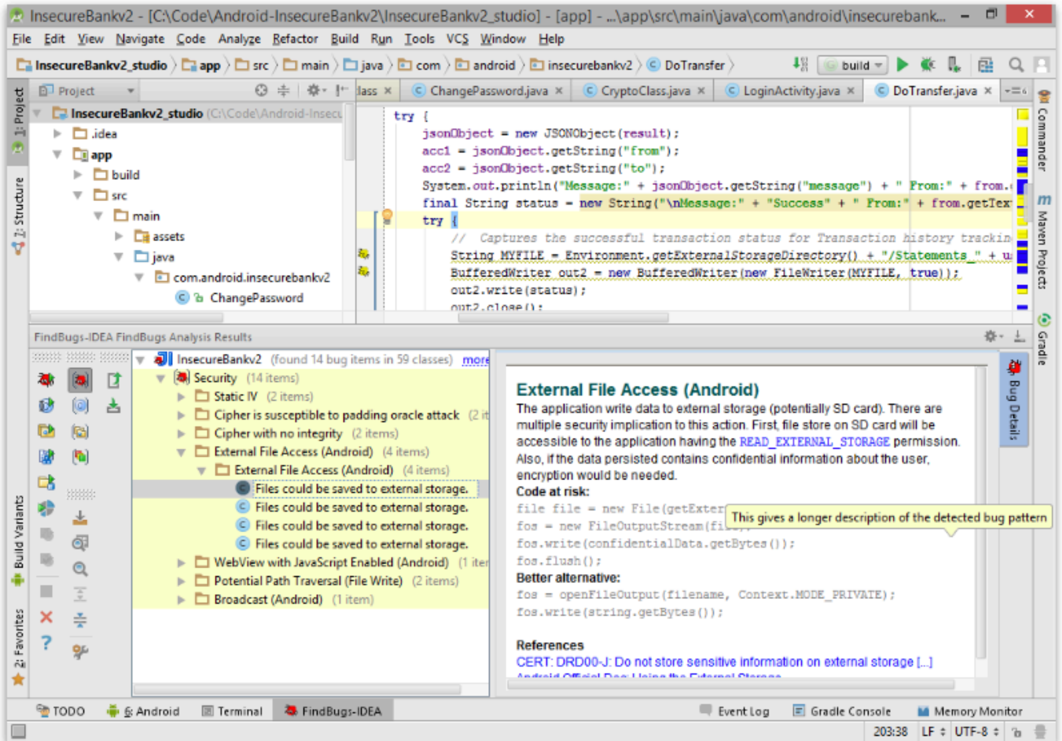
FindBugs Bug Descriptions

This document lists the standard bug patterns reported by FindBugs version 3.0.1.

Summary

Description	Category
BC: Equals method should not assume anything about the type of its argument	Bad practice
BIT: Check for sign of bitwise operation	Bad practice
CN: Class implements Cloneable but does not define or use clone method	Bad practice
CN: clone method does not call super.clone()	Bad practice
CN: Class defines clone() but doesn't implement Cloneable	Bad practice
CNT: Rough value of known constant found	Bad practice
Co: Abstract class defines covariant compareTo() method	Bad practice
Co: compareTo()/compare() incorrectly handles float or double value	Bad practice
Co: compareTo()/compare() returns Integer.MIN_VALUE	Bad practice
Co: Covariant compareTo() method defined	Bad practice
DE: Method might drop exception	Bad practice
DE: Method might ignore exception	Bad practice
DMI: Adding elements of an entry set may fail due to reuse of Entry objects	Bad practice
DMI: Random object created and used only once	Bad practice
DMI: Don't use removeAll to clear a collection	Bad practice
Dm: Method invokes System.exit(...)	Bad practice
Dm: Method invokes dangerous method runFinalizersOnExit	Bad practice
ES: Comparison of String parameter using == or !=	Bad practice
ES: Comparison of String objects using == or !=	Bad practice
Eq: Abstract class defines covariant equals() method	Bad practice
Eq: Equals checks for incompatible operand	Bad practice
Eq: Class defines compareTo(...) and uses Object.equals()	Bad practice
Eq: equals method fails for subtypes	Bad practice
Eq: Covariant equals() method defined	Bad practice
FI: Empty finalizer should be deleted	Bad practice
FI: Explicit invocation of finalizer	Bad practice
FI: Finalizer nulls fields	Bad practice
FI: Finalizer only nulls fields	Bad practice
FI: Finalizer does not call superclass finalizer	Bad practice
FI: Finalizer nullifies superclass finalizer	Bad practice
FI: Finalizer does nothing but call superclass finalizer	Bad practice
FS: Format string should use %n rather than \n	Bad practice
GC: Unchecked type in generic call	Bad practice
HE: Class defines equals() but not hashCode()	Bad practice
HE: Class defines equals() and uses Object.hashCode()	Bad practice
HE: Class defines hashCode() but not equals()	Bad practice
HE: Class defines hashCode() and uses Object.equals()	Bad practice
HE: Class inherits equals() and uses Object.hashCode()	Bad practice
IC: Superclass uses subclass during initialization	Bad practice
IMSE: Dubious catching of IllegalMonitorStateException	Bad practice
ISC: Needless instantiation of class that only supplies static methods	Bad practice
It: Iterator next() method can't throw NoSuchElementException	Bad practice
J2EE: Store of non serializable object into HttpSession	Bad practice
JCIP: Fields of immutable classes should be final	Bad practice
ME: Public enum method unconditionally sets its field	Bad practice

SpotBugs can be Extended with Plugins


InsecureBankv2 - [C:\Code\Android-InsecureBankv2\InsecureBankv2_studio] - [app] - ...\app\src\main\java\com\android\insecurebank...
File Edit View Navigate Code Analyze Refactor Build Run Tools VCS Window Help
InsecureBankv2_studio app src main java com android insecurebankv2 DoTransfer
build
Project
ChangePassword.java
CryptoClass.java
LoginActivity.java
DoTransfer.java
InsecureBankv2_studio
.idea
app
build
src
main
assets
java
com.android.insecurebankv2
ChangePassword
FindBugs-IDEA FindBugs Analysis Results
Commander
Maven Projects
Gradle
Bug Details
Build Variants
2: Favorites
TODO
6: Android
Terminal
FindBugs-IDEA
Event Log
Gradle Console
Memory Monitor
203:38 LF UTF-8

```
try {
    jsonObject = new JSONObject(result);
    acc1 = jsonObject.getString("from");
    acc2 = jsonObject.getString("to");
    System.out.println("Message:" + jsonObject.getString("message") + " From:" + from.
    final String status = new String("\nMessage:" + "Success" + " From:" + from.getTex
    try {
        //  Captures the successful transaction status for Transaction history trackin
        String MYFILE = Environment.getExternalStorageDirectory() + "/Statements_" + u
        BufferedWriter out2 = new BufferedWriter(new FileWriter(MYFILE, true));
        out2.write(status);
        out2.close();
```

- InsecureBankv2 (found 14 bug items in 59 classes) more
  - Security (14 items)
    - Static IV (2 items)
    - Cipher is susceptible to padding oracle attack (2 it
    - Cipher with no integrity (2 items)
    - External File Access (Android) (4 items)
      - External File Access (Android) (4 items)
        - Files could be saved to external storage.
        - Files could be saved to external storage.
        - Files could be saved to external storage.
        - Files could be saved to external storage.
    - WebView with JavaScript Enabled (Android) (1 iter
    - Potential Path Traversal (File Write) (2 items)
    - Broadcast (Android) (1 item)

External File Access (Android)

The application write data to external storage (potentially SD card). There are multiple security implication to this action. First, file store on SD card will be accessible to the application having the `READ_EXTERNAL_STORAGE` permission. Also, if the data persisted contains confidential information about the user, encryption would be needed.

Code at risk:

```
file file = new File(getExter
fos = new FileOutputStream(fi
fos.write(confidentialData.getBytes());
fos.flush();
```

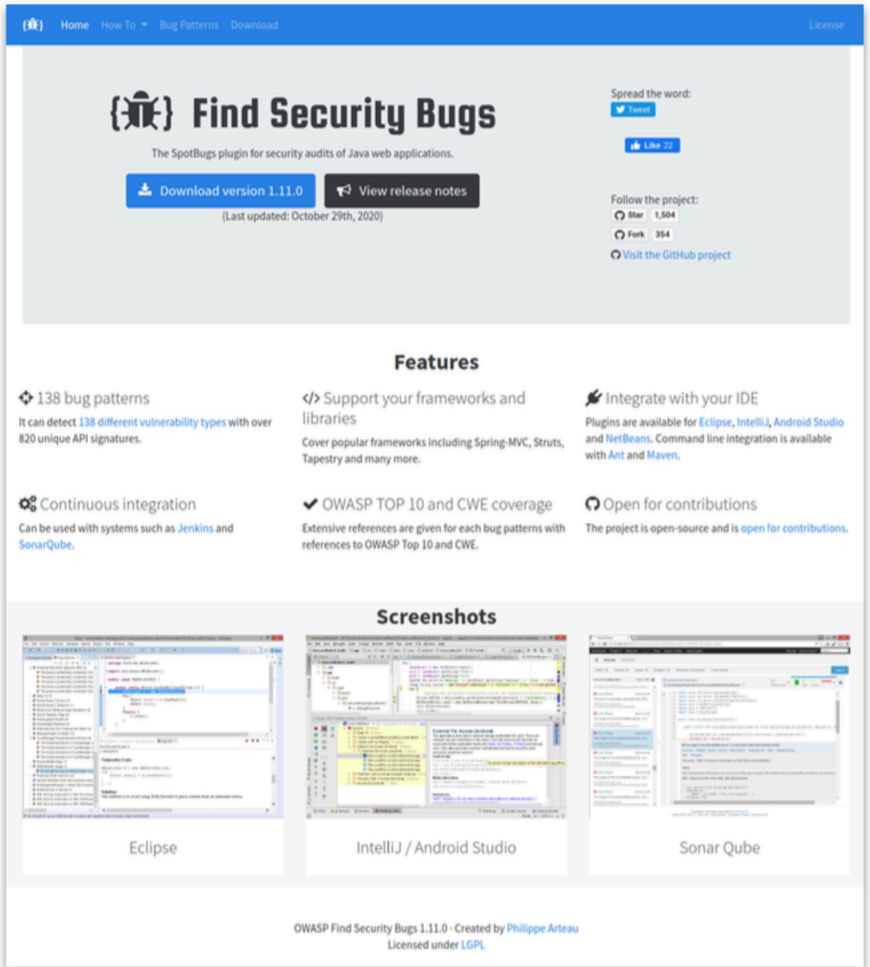
This gives a longer description of the detected bug pattern

Better alternative:

```
fos = openFileOutput(filename, Context.MODE_PRIVATE);
fos.write(string.getBytes());
```

References

CERT: DRD00-J: Do not store sensitive information on external storage [...]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Bug Patterns
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Like 22
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Star 1,504
Fork 354
Visit the GitHub project
Eclipse
IntelliJ / Android Studio
Sonar Qube

Find Security Bugs

The SpotBugs plugin for security audits of Java web applications.

(Last updated: October 29th, 2020)

Features

138 bug patterns
It can detect 138 different vulnerability types with over 820 unique API signatures.

Support your frameworks and libraries
Cover popular frameworks including Spring-MVC, Struts, Tapestry and many more.

Integrate with your IDE
Plugins are available for Eclipse, IntelliJ, Android Studio and NetBeans. Command line integration is available with Ant and Maven.

Continuous integration
Can be used with systems such as Jenkins and SonarQube.

OWASP TOP 10 and CWE coverage
Extensive references are given for each bug patterns with references to OWASP Top 10 and CWE.

Open for contributions
The project is open-source and is open for contributions.

Screenshots

OWASP Find Security Bugs 1.11.0 · Created by Philippe Arteau
Licensed under LGPL

Challenges

- The analysis must produce zero false positives
  - Otherwise developers won’t be able to build the code!
- The analysis needs to be really fast
  - Ideally < 100 ms
  - If it takes longer, developers will become irritated and lose productivity
- You can’t just “turn on” a particular check
  - Every instance where that check fails will prevent existing code from
  - There could be thousands of violations for a single check across large codebases

(3) -Use Type Annotations to Detect Common Errors

- Uses a conservative analysis to prove the absence of certain defects
  - Null pointer errors, uninitialized fields, certain liveness issues, information leaks, SQL injections, bad regular expressions, incorrect physical units, bad format strings, ...
  - C.f. SpotBugs which makes no safety guarantees
  - Assuming that code is annotated and those annotations are correct
- Uses annotations to enhance type system
- Example: Java Checker Framework or MyPy

CHECKER framework

(3) -Use Type Annotations to Detect Common Errors

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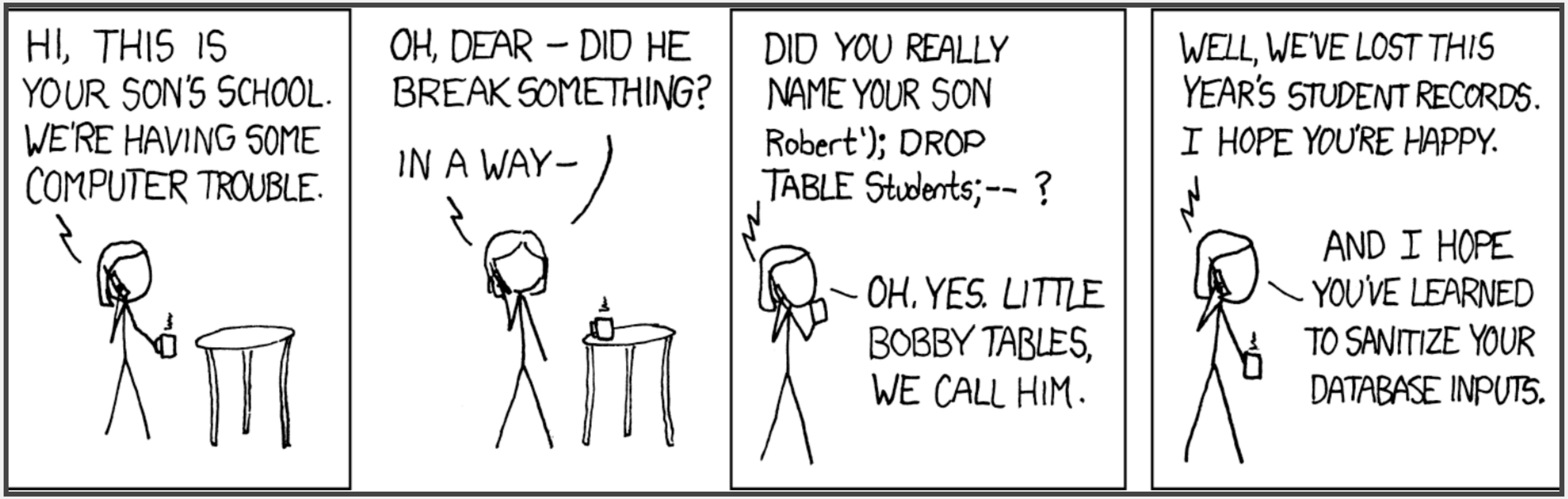
- Example: Java Checker Framework or MyPy

Taint Analysis

- Tracks flow of sensitive information through the program
- Tainted inputs come from arbitrary, possibly malicious sources
  - User inputs, unvalidated data
- Using tainted inputs may have dangerous consequences
  - Program crash, data corruption, leak private data, etc.
- We need to check that inputs are sanitized before reaching sensitive locations

Classic Example: SQL Injection


HI, THIS IS YOUR SON'S SCHOOL. WE'RE HAVING SOME COMPUTER TROUBLE.
OH, DEAR – DID HE BREAK SOMETHING?
IN A WAY–
DID YOU REALLY NAME YOUR SON Robert'); DROP TABLE Students;-- ?
OH. YES. LITTLE BOBBY TABLES, WE CALL HIM.
WELL, WE'VE LOST THIS YEAR'S STUDENT RECORDS. I HOPE YOU'RE HAPPY.
AND I HOPE YOU'VE LEARNED TO SANITIZE YOUR DATABASE INPUTS.

Classic Example: SQL Injection

```
void processRequest() {
String input = getUserInput();
String query = "SELECT ... " + input;
executeQuery(query);
}
```

Classic Example: SQL Injection

```
void processRequest() {
String input = getUserInput();
String query = "SELECT ... " + input;
executeQuery(query);
}
```

Tainted input arrives from untrusted source

Tainted output flows to a sensitive sink

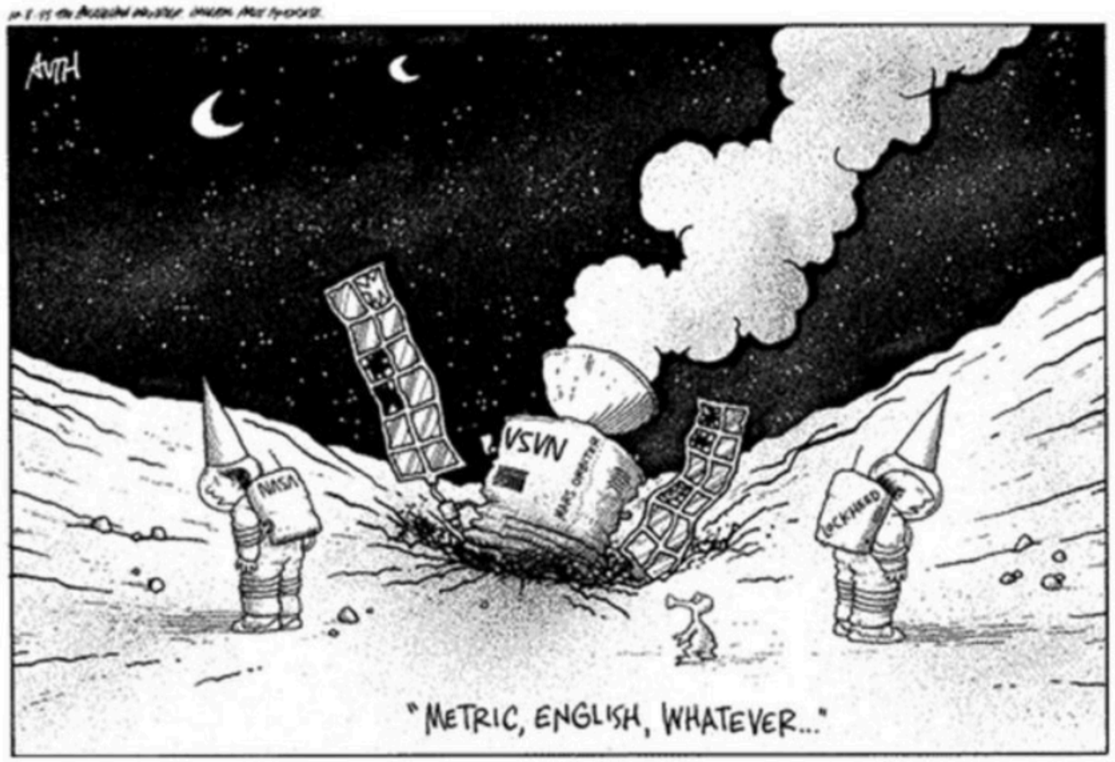
Classic Example: SQL Injection

```
void processRequest() {
String input = getUserInput();

input = sanitizeInput(input);

String query = "SELECT ... " + input;
executeQuery(query);

}
```

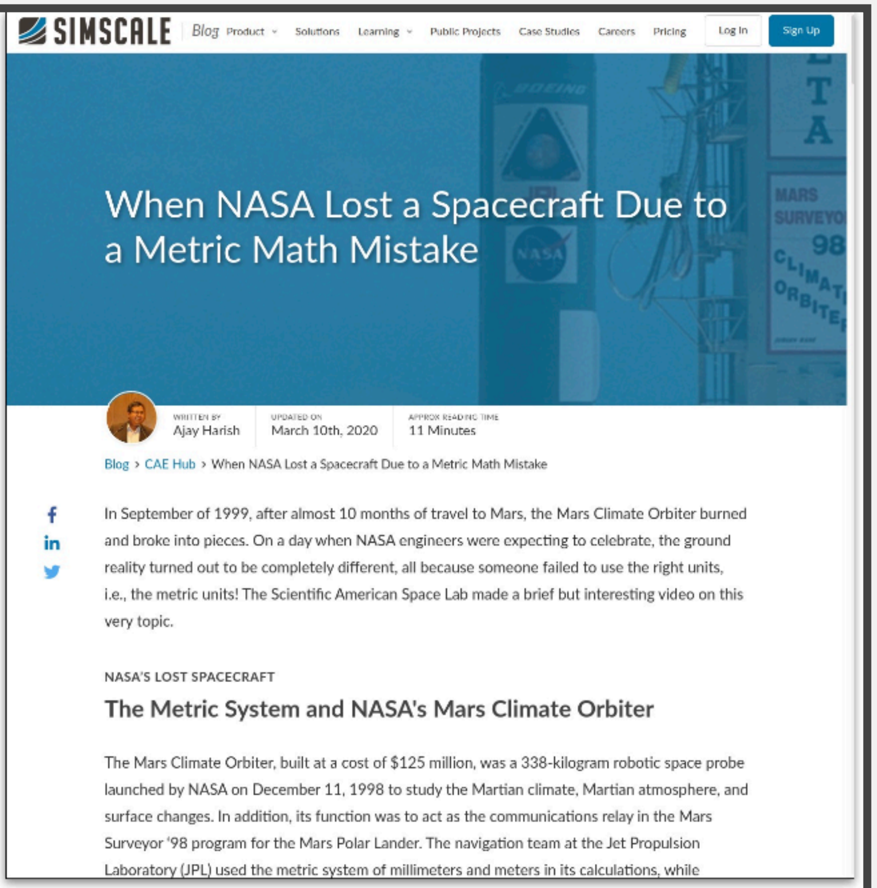
Taint is removed by sanitizing data

We can now safely execute query on untainted data

Unit Catastrophe


AUTH
VSVN
NASA
MARS ORBITER
LOCKHEED
"METRIC, ENGLISH, WHATEVER..."

Remember the Mars Climate Orbiter incident from 1999?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When NASA Lost a Spacecraft Due to a Metric Math Mistake

WRITTEN BY Ajay Harish
UPDATED ON March 10th, 2020
APPROX READING TIME 11 Minutes

Blog > CAE Hub > When NASA Lost a Spacecraft Due to a Metric Math Mistake

In September of 1999, after almost 10 months of travel to Mars, the Mars Climate Orbiter burned and broke into pieces. On a day when NASA engineers were expecting to celebrate, the ground reality turned out to be completely different, all because someone failed to use the right units, i.e., the metric units! The Scientific American Space Lab made a brief but interesting video on this very topic.

NASA'S LOST SPACECRAFT

The Metric System and NASA's Mars Climate Orbiter

The Mars Climate Orbiter, built at a cost of $125 million, was a 338-kilogram robotic space probe launched by NASA on December 11, 1998 to study the Martian climate, Martian atmosphere, and surface changes. In addition, its function was to act as the communications relay in the Mars Surveyor '98 program for the Mars Polar Lander. The navigation team at the Jet Propulsion Laboratory (JPL) used the metric system of millimeters and meters in its calculations, while

NASA's Mars Climate Orbiter (cost of $327 million) was lost because of a discrepancy between use of metric unit Newtons and imperial measure Pound-force.

Units Checker Identifies Physical Unit Inconsistencies

- Guarantees that operations are performed on the same kinds and units

- Kinds of annotations
  - @Acceleration, @Angle, @Area, @Current, @Length, @Luminance, @Mass, @Speed, @Substance, @Temperature, @Time

- SI unit annotation
  - @m, @km, @mm, @kg, @mPERs, @mPERs2, @radians, @degrees, @A, ...

Checker Frameworks: Limitations

- Can only analyze code that is annotated
  - Requires that dependent libraries are also annotated
  - Can be tricky, but not impossible, to retrofit annotations into existing codebases

- Only considers the signature and annotations of methods
  - Doesn’t look at the implementation of methods that are being called

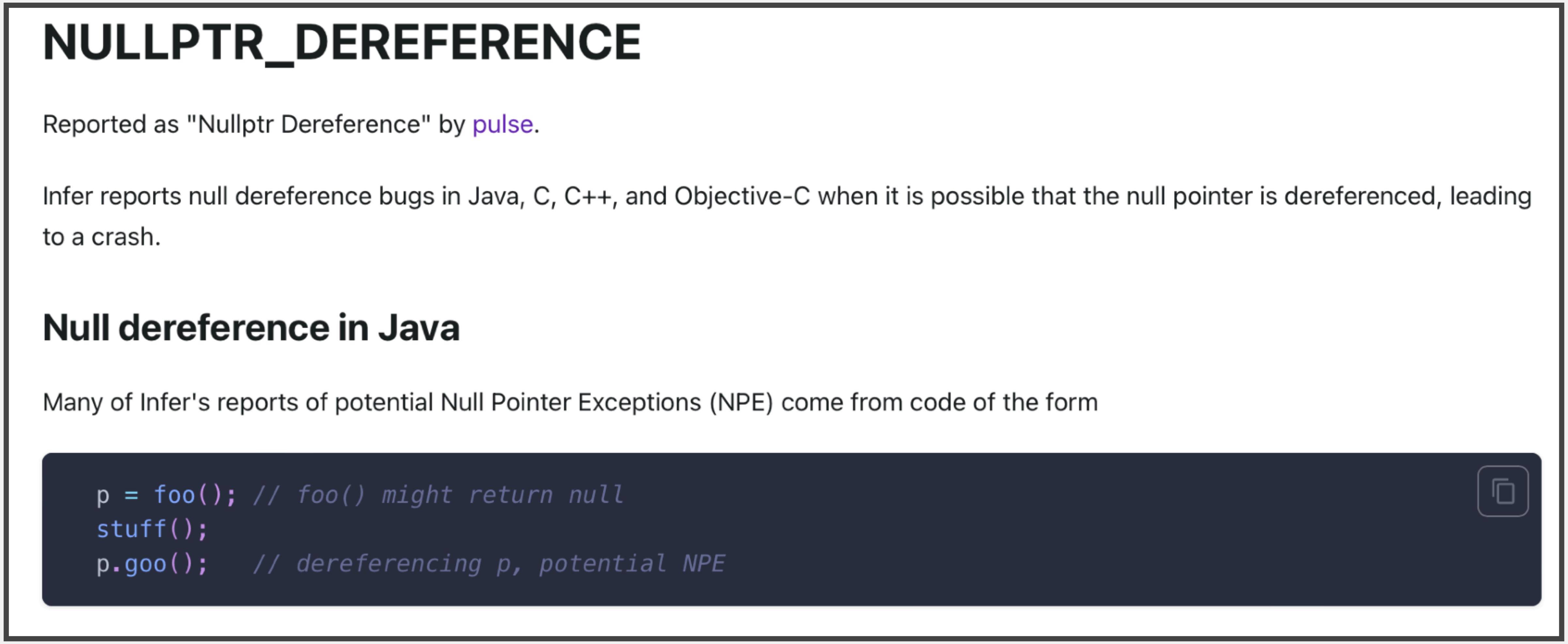
- Dynamically generated code
  - Spring Framework

- • Can produce false positives!
  - Byproduct of necessary approximations

Infer: What if we didn't want Annotations

- Focused on memory safety bugs
  - Null pointer dereferences, memory leaks, resource leaks, ...
- Compositional interprocedural reasoning
  - Based on separation logic and bi-abduction
- Scalable and fast
  - Can run incremental analysis on changed code
- Does not require annotations
- Supports multiple languages
  - Java, C, C++, Objective-C
  - Programs are compiled to an intermediate representation

Infer: What if we didn't want Annotations



NULLPTR_DEREFERENCE

Reported as "Nullptr Dereference" by pulse.

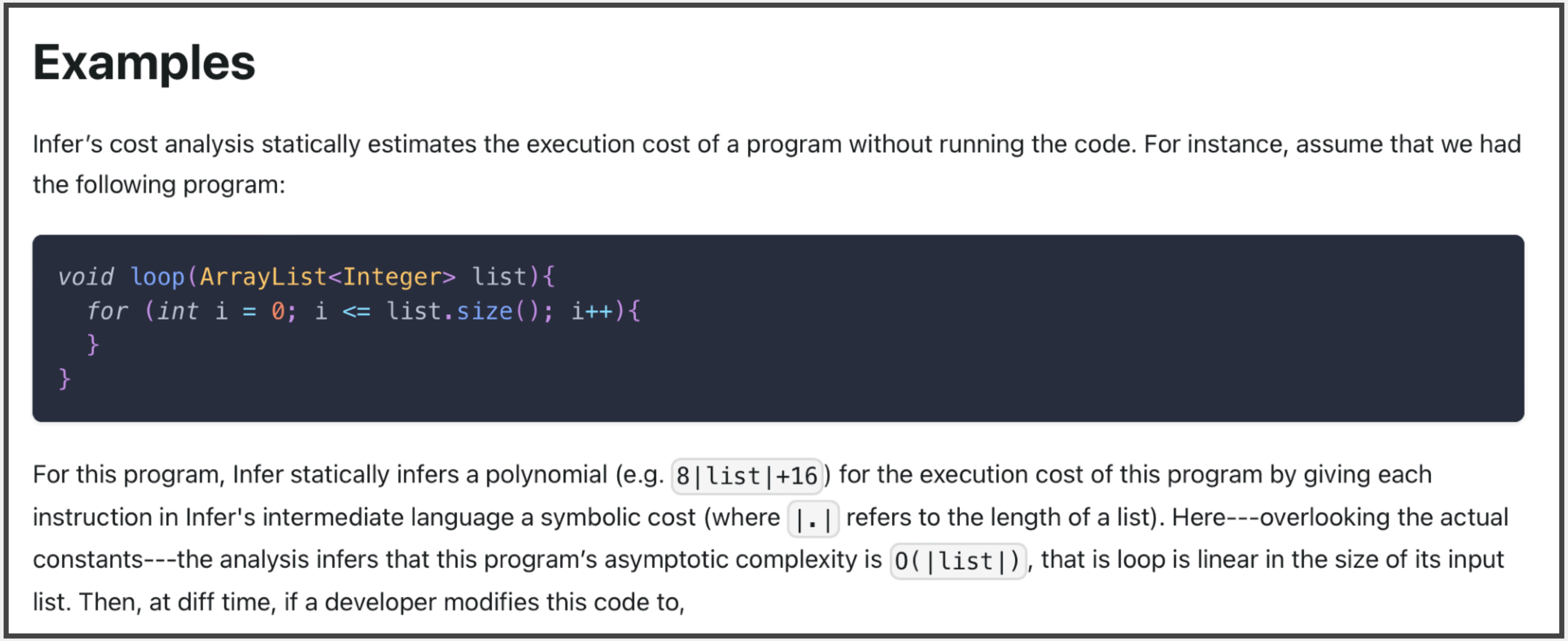
Infer reports null dereference bugs in Java, C, C++, and Objective-C when it is possible that the null pointer is dereferenced, leading to a crash.

Null dereference in Java

Many of Infer's reports of potential Null Pointer Exceptions (NPE) come from code of the form

```
p = foo(); // foo() might return null
stuff();
p.goo();   // dereferencing p, potential NPE
```

Infer: What if we didn’t want Annotations



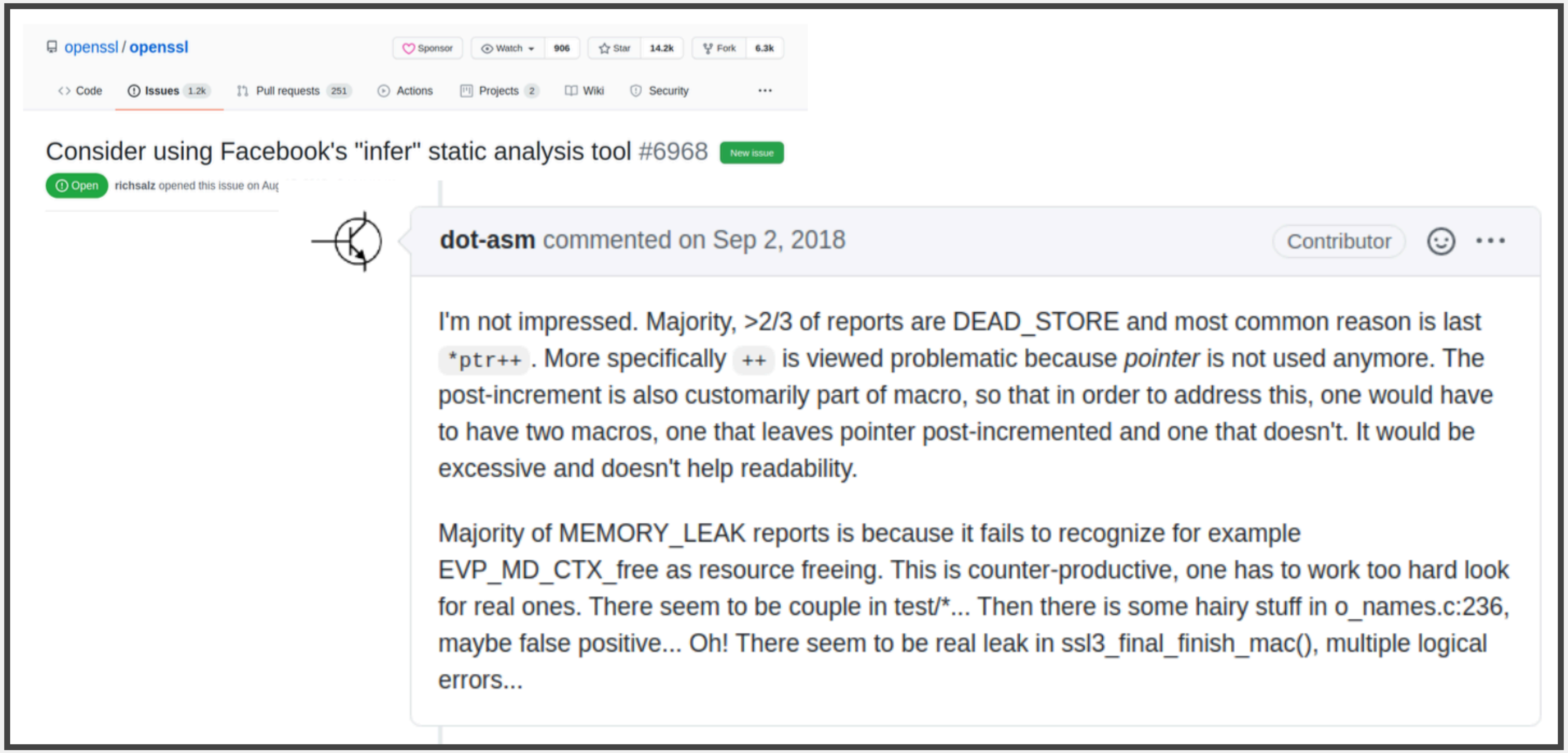
Examples

Infer’s cost analysis statically estimates the execution cost of a program without running the code. For instance, assume that we had the following program:

```
void loop(ArrayList<Integer> list){
  for (int i = 0; i <= list.size(); i++){
  }
}
```

For this program, Infer statically infers a polynomial (e.g. `8|list|+16`) for the execution cost of this program by giving each instruction in Infer's intermediate language a symbolic cost (where `|.|` refers to the length of a list). Here---overlooking the actual constants---the analysis infers that this program’s asymptotic complexity is `O(|list|)`, that is loop is linear in the size of its input list. Then, at diff time, if a developer modifies this code to,

Beware of Inevitable False Positives


openssl / openssl
Sponsor
Watch 906
Star 14.2k
Fork 6.3k
Code
Issues 1.2k
Pull requests 251
Actions
Projects 2
Wiki
Security
New issue
Open
Contributor

Consider using Facebook's "infer" static analysis tool #6968

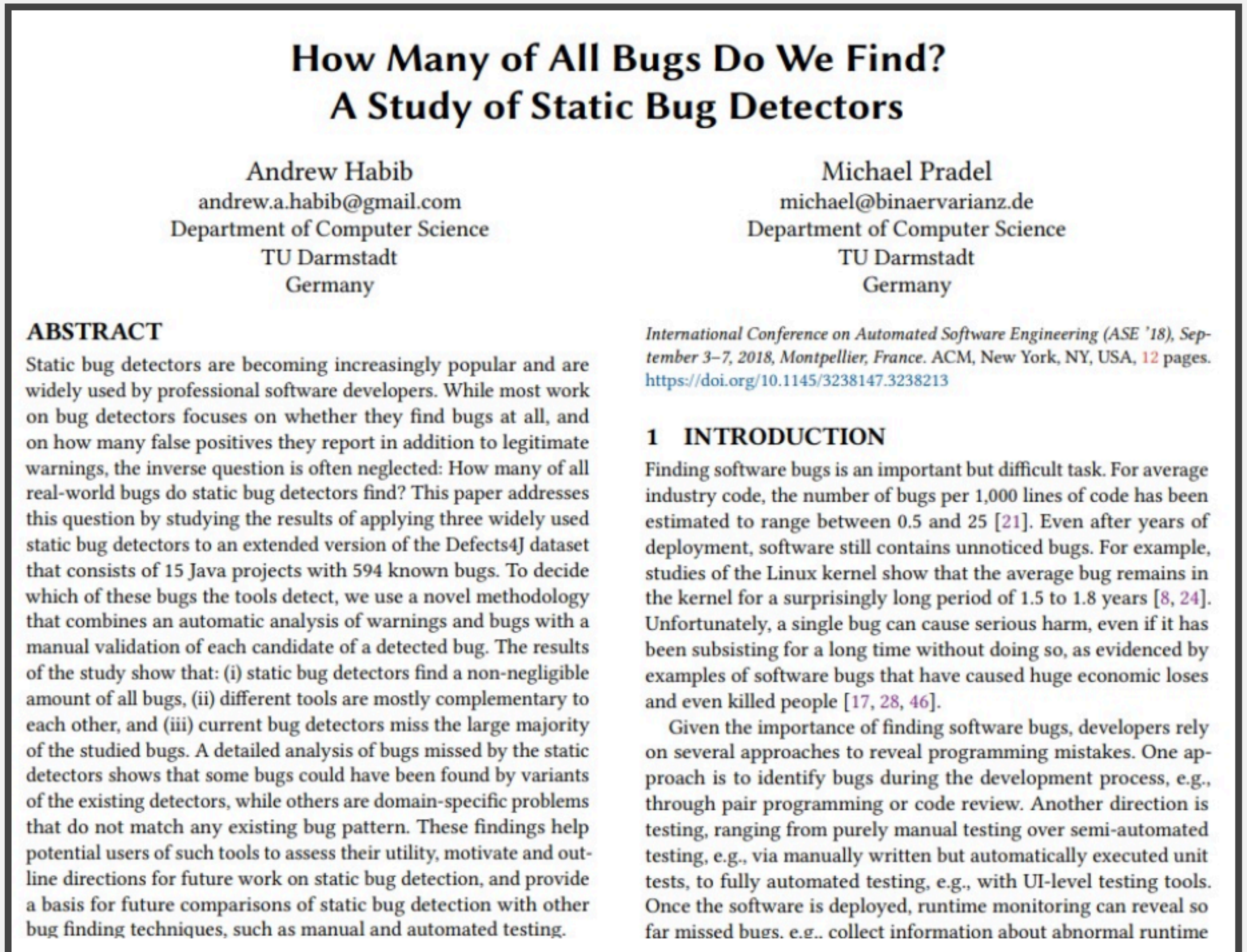
richsalz opened this issue on Au

dot-asm commented on Sep 2, 2018

I'm not impressed. Majority, >2/3 of reports are DEAD_STORE and most common reason is last `*ptr++`. More specifically `++` is viewed problematic because *pointer* is not used anymore. The post-increment is also customarily part of macro, so that in order to address this, one would have to have two macros, one that leaves pointer post-incremented and one that doesn't. It would be excessive and doesn't help readability.

Majority of MEMORY_LEAK reports is because it fails to recognize for example EVP_MD_CTX_free as resource freeing. This is counter-productive, one has to work too hard look for real ones. There seem to be couple in test/*... Then there is some hairy stuff in o_names.c:236, maybe false positive... Oh! There seem to be real leak in ssl3_final_finish_mac(), multiple logical errors...

The Best QA Strategies use Multiple Tools



How Many of All Bugs Do We Find?
A Study of Static Bug Detectors

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TU Darmstadt
Germany

ABSTRACT

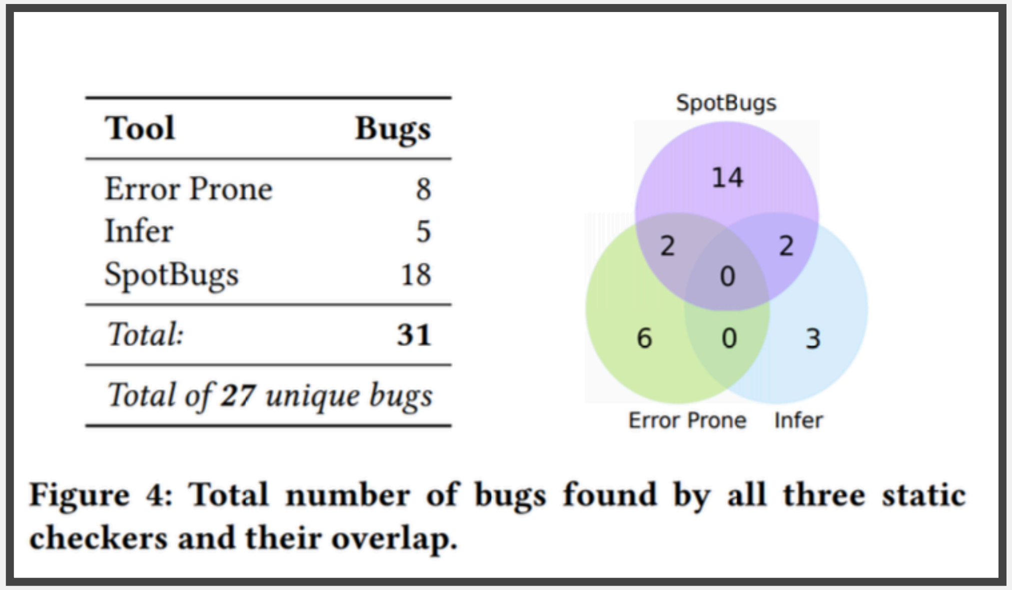
Static bug detectors are becoming increasingly popular and are widely used by professional software developers. While most work on bug detectors focuses on whether they find bugs at all, and on how many false positives they report in addition to legitimate warnings, the inverse question is often neglected: How many of all real-world bugs do static bug detectors find? This paper addresses this question by studying the results of applying three widely used static bug detectors to an extended version of the Defects4J dataset that consists of 15 Java projects with 594 known bugs. To decide which of these bugs the tools detect, we use a novel methodology that combines an automatic analysis of warnings and bugs with a manual validation of each candidate of a detected bug. The results of the study show that: (i) static bug detectors find a non-negligible amount of all bugs, (ii) different tools are mostly complementary to each other, and (iii) current bug detectors miss the large majority of the studied bugs. A detailed analysis of bugs missed by the static detectors shows that some bugs could have been found by variants of the existing detectors, while others are domain-specific problems that do not match any existing bug pattern. These findings help potential users of such tools to assess their utility, motivate and outline directions for future work on static bug detection, and provide a basis for future comparisons of static bug detection with other bug finding techniques, such as manual and automated testing.

International Conference on Automated Software Engineering (ASE '18), September 3–7, 2018, Montpellier, France. ACM, New York, NY, USA, 12 pages. https://doi.org/10.1145/3238147.3238213

1 INTRODUCTION

Finding software bugs is an important but difficult task. For average industry code, the number of bugs per 1,000 lines of code has been estimated to range between 0.5 and 25 [21]. Even after years of deployment, software still contains unnoticed bugs. For example, studies of the Linux kernel show that the average bug remains in the kernel for a surprisingly long period of 1.5 to 1.8 years [8, 24]. Unfortunately, a single bug can cause serious harm, even if it has been subsisting for a long time without doing so, as evidenced by examples of software bugs that have caused huge economic loses and even killed people [17, 28, 46].

Given the importance of finding software bugs, developers rely on several approaches to reveal programming mistakes. One approach is to identify bugs during the development process, e.g., through pair programming or code review. Another direction is testing, ranging from purely manual testing over semi-automated testing, e.g., via manually written but automatically executed unit tests, to fully automated testing, e.g., with UI-level testing tools. Once the software is deployed, runtime monitoring can reveal so far missed bugs, e.g., collect information about abnormal runtime

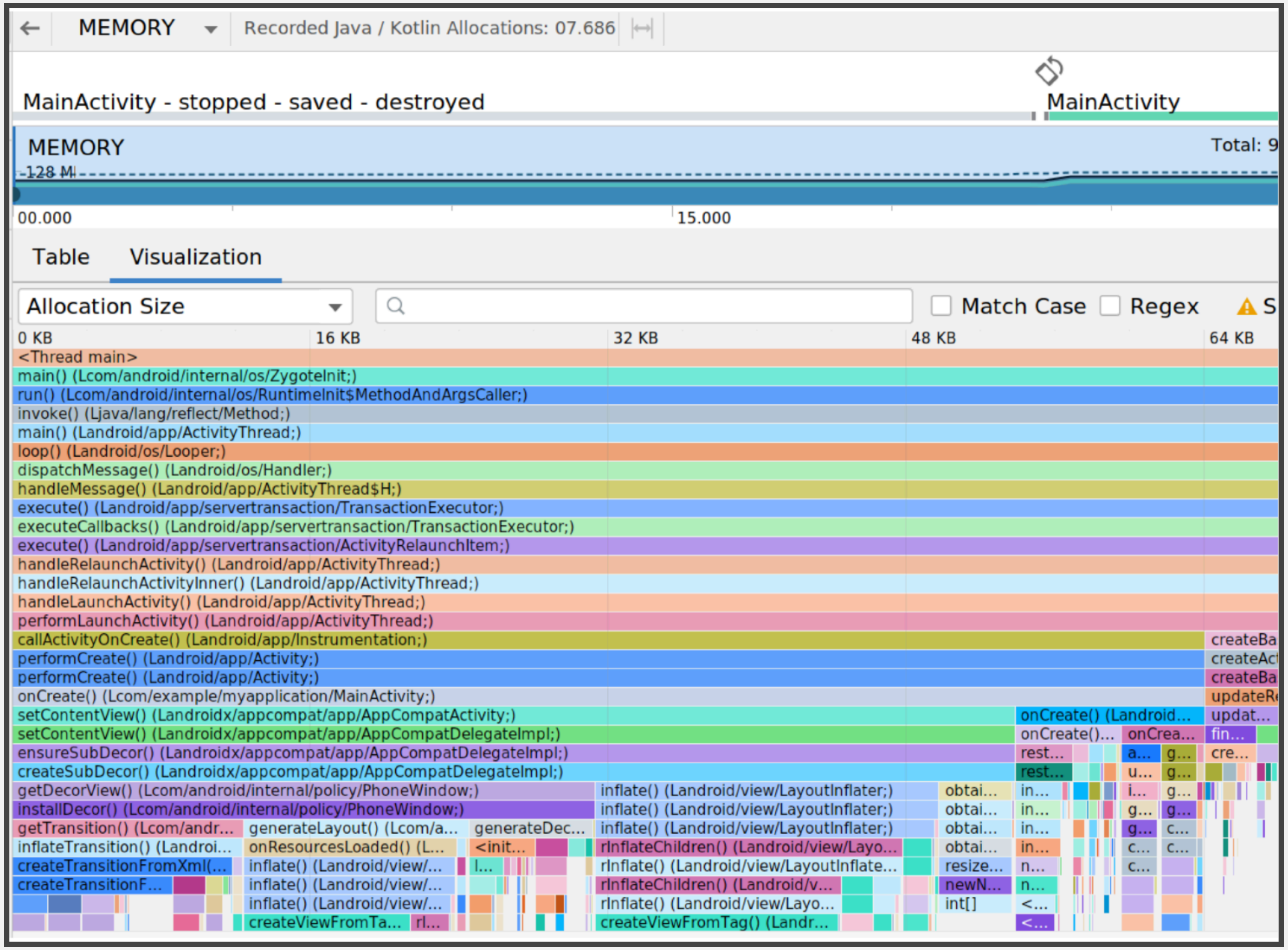


Tool	Bugs
Error Prone	8
Infer	5
SpotBugs	18
Total:	**31**
Total of 27 unique bugs	

Figure 4: Total number of bugs found by all three static checkers and their overlap.

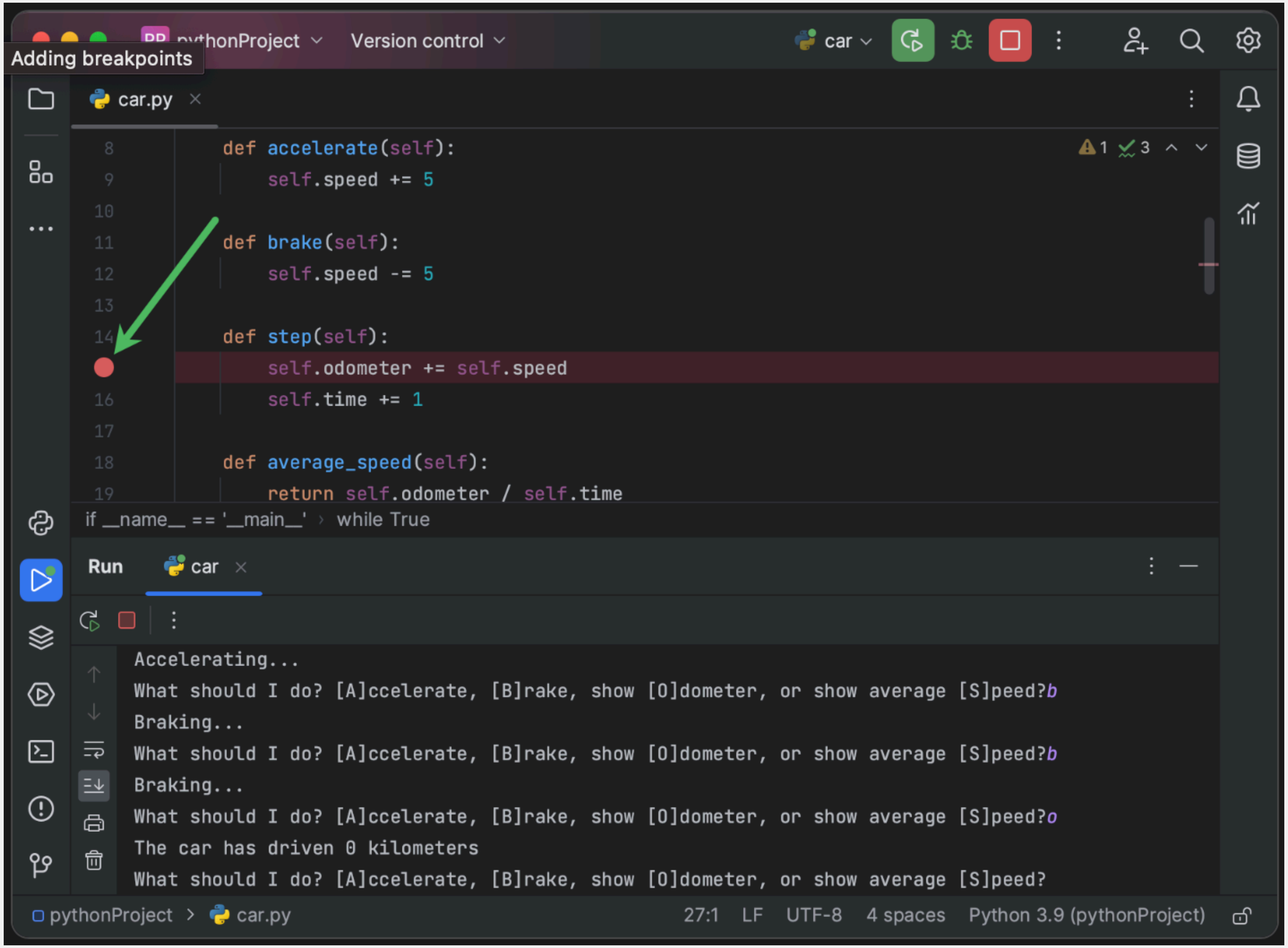
Dynamic Analysis

Android Memory Profiler


MEMORY
Recorded Java / Kotlin Allocations: 07.686
MainActivity - stopped - saved - destroyed
MainActivity
MEMORY
Total: 9
128 M
00.000
15.000
Table
Visualization
Allocation Size
☐ Match Case
☐ Regex
0 KB
16 KB
32 KB
48 KB
64 KB
<Thread main>
main() (Lcom/android/internal/os/ZygoteInit;)
run() (Lcom/android/internal/os/RuntimeInit$MethodAndArgsCaller;)
invoke() (Ljava/lang/reflect/Method;)
main() (Landroid/app/ActivityThread;)
loop() (Landroid/os/Looper;)
dispatchMessage() (Landroid/os/Handler;)
handleMessage() (Landroid/app/ActivityThread$H;)
execute() (Landroid/app/servertransaction/TransactionExecutor;)
executeCallbacks() (Landroid/app/servertransaction/TransactionExecutor;)
execute() (Landroid/app/servertransaction/ActivityRelaunchItem;)
handleRelaunchActivity() (Landroid/app/ActivityThread;)
handleRelaunchActivityInner() (Landroid/app/ActivityThread;)
handleLaunchActivity() (Landroid/app/ActivityThread;)
performLaunchActivity() (Landroid/app/ActivityThread;)
callActivityOnCreate() (Landroid/app/Instrumentation;)
performCreate() (Landroid/app/Activity;)
performCreate() (Landroid/app/Activity;)
onCreate() (Lcom/example/myapplication/MainActivity;)
setContentView() (Landroidx/appcompat/app/AppCompatActivity;)
setContentView() (Landroidx/appcompat/app/AppCompatDelegateImpl;)
ensureSubDecor() (Landroidx/appcompat/app/AppCompatDelegateImpl;)
createSubDecor() (Landroidx/appcompat/app/AppCompatDelegateImpl;)
getDecorView() (Lcom/android/internal/policy/PhoneWindow;)
installDecor() (Lcom/android/internal/policy/PhoneWindow;)
getTransition() (Lcom/andr...
inflateTransition() (Landroi...
createTransitionFromXml(...
createTransitionF...
generateLayout() (Lcom/a...
onResourcesLoaded() (L...
inflate() (Landroid/view/...
inflate() (Landroid/view/...
inflate() (Landroid/view/...
createViewFromTa...
generateDec...
<init...
inflate() (Landroid/view/LayoutInflater;)
inflate() (Landroid/view/LayoutInflater;)
inflate() (Landroid/view/LayoutInflater;)
rInflateChildren() (Landroid/view/Layo...
rInflate() (Landroid/view/LayoutInflate...
rInflateChildren() (Landroid/v...
rInflate() (Landroid/view/Layo...
createViewFromTag() (Landr...
obtai...
resize...
newN...
int[]
onCreate() (Landroid...
onCreate()...
onCrea...
rest...
createBa
createAct
createBa
updateRe
updat...
fin...
cre...

https://developer.android.com/studio/profile/memory-profiler

Pycharm Debugger



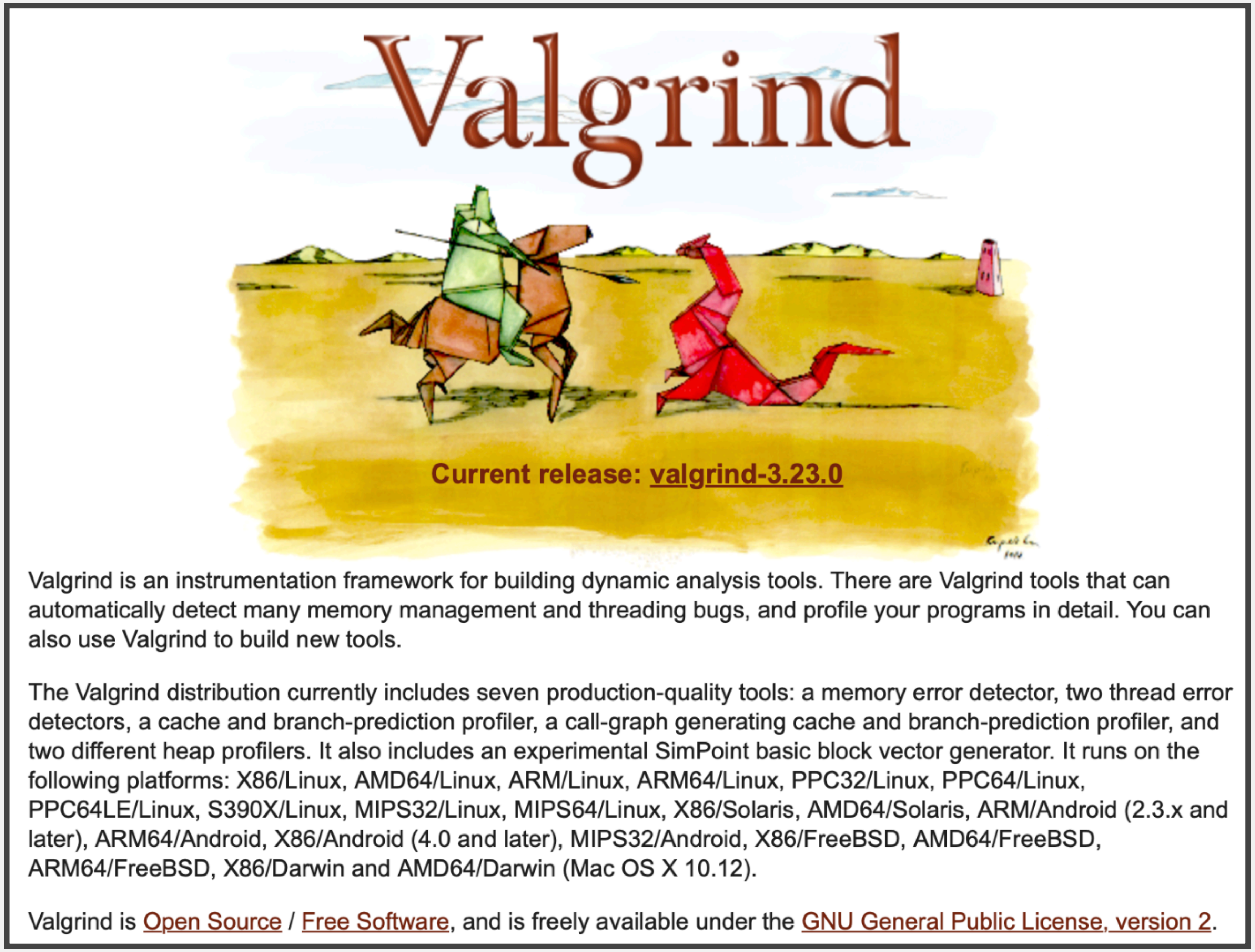
Adding breakpoints
pythonProject
Version control
car
car.py
if __name__ == '__main__' › while True
Run
car
pythonProject › car.py
27:1 LF UTF-8 4 spaces Python 3.9 (pythonProject)

```python
    def accelerate(self):
        self.speed += 5

    def brake(self):
        self.speed -= 5

    def step(self):
        self.odometer += self.speed
        self.time += 1

    def average_speed(self):
        return self.odometer / self.time
```

```
Accelerating...
What should I do? [A]ccelerate, [B]rake, show [O]dometer, or show average [S]peed?b
Braking...
What should I do? [A]ccelerate, [B]rake, show [O]dometer, or show average [S]peed?b
Braking...
What should I do? [A]ccelerate, [B]rake, show [O]dometer, or show average [S]peed?o
The car has driven 0 kilometers
What should I do? [A]ccelerate, [B]rake, show [O]dometer, or show average [S]peed?
```

https://www.jetbrains.com/help/pycharm/debugging-your-first-python-application.html#where-is-the-problem

Valgrind Dynamic Analysis Library



Current release: valgrind-3.23.0

Valgrind is an instrumentation framework for building dynamic analysis tools. There are Valgrind tools that can automatically detect many memory management and threading bugs, and profile your programs in detail. You can also use Valgrind to build new tools.

The Valgrind distribution currently includes seven production-quality tools: a memory error detector, two thread error detectors, a cache and branch-prediction profiler, a call-graph generating cache and branch-prediction profiler, and two different heap profilers. It also includes an experimental SimPoint basic block vector generator. It runs on the following platforms: X86/Linux, AMD64/Linux, ARM/Linux, ARM64/Linux, PPC32/Linux, PPC64/Linux, PPC64LE/Linux, S390X/Linux, MIPS32/Linux, MIPS64/Linux, X86/Solaris, AMD64/Solaris, ARM/Android (2.3.x and later), ARM64/Android, X86/Android (4.0 and later), MIPS32/Android, X86/FreeBSD, AMD64/FreeBSD, ARM64/FreeBSD, X86/Darwin and AMD64/Darwin (Mac OS X 10.12).

Valgrind is Open Source / Free Software, and is freely available under the GNU General Public License, version 2.

https://valgrind.org/

Summary

- Linters are cheap, fast, but imprecise analysis tools
  - Can be used for purposes other than bug detection (e.g., style)

- Conservative analyzers can demonstrate the absence of particular defects
  - At the cost of false positives due to necessary approximations
  - Inevitable trade-off between false positives and false negatives

- The best QA strategy involves multiple analysis and testing techniques
  - The exact set of tools and techniques depends on context