Evolutionary Fuzzing for Genetic Improvement

Toward Adaptive Software Defense

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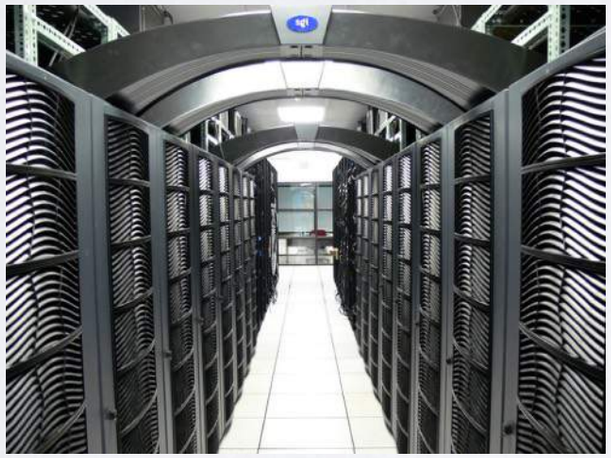
What Is The Problem We Are Trying To Solve?

Ecosystems lacking sufficient diversity lack adaptability and can easily falter and fail.

Problem: The low initial cost of same software everywhere has made our systems vulnerable and easy prey for widespread attack. *Attackers have a huge asymmetric advantage.*



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Solution:

- Avoid unnecessary consistency.
- Implement facile and distributed moving target defense strategies.
- Use biology as inspiration.

Simulated software diversity

Genetic Improvement For Defense

We can use GI to create neutral variants

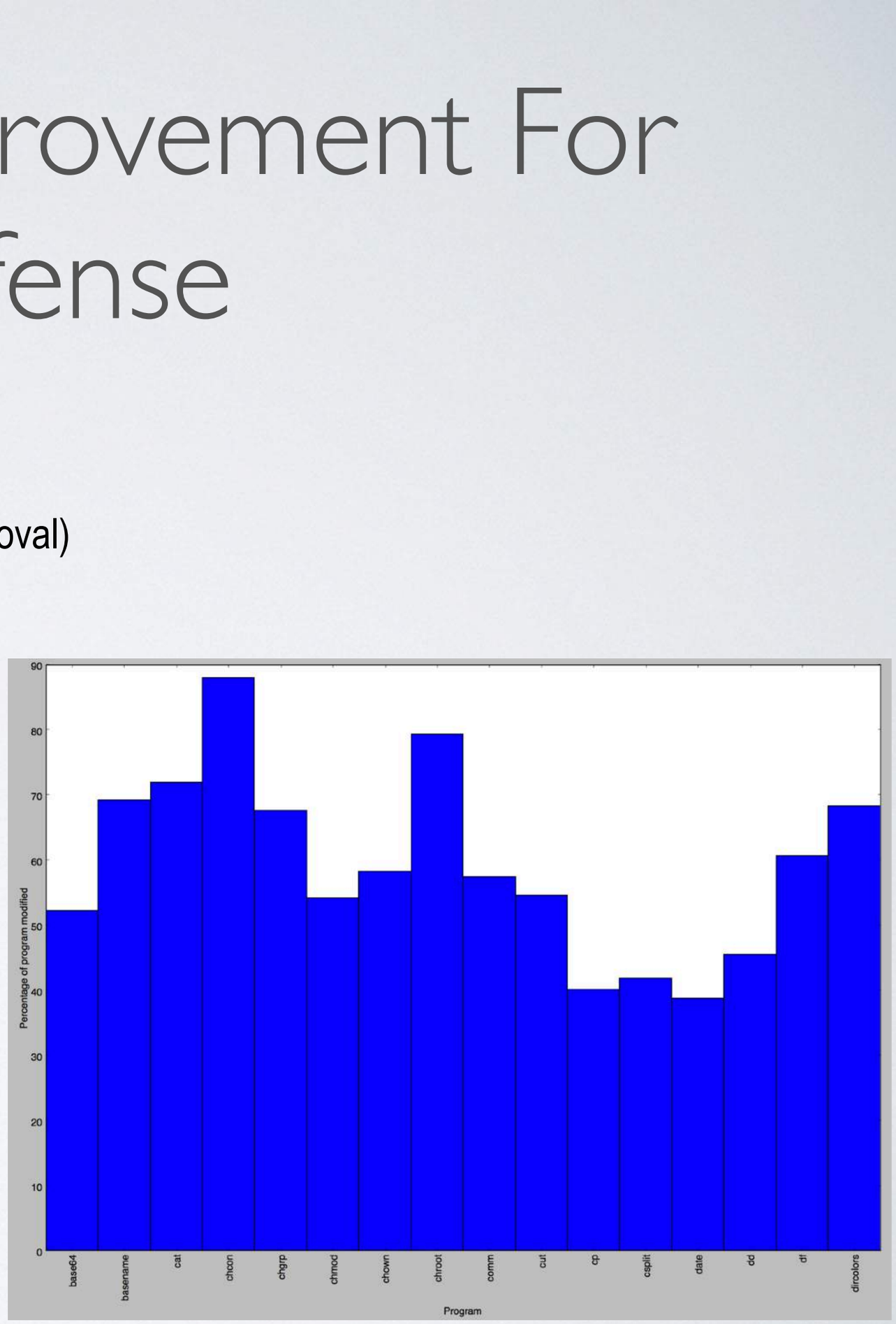
- Increase the likelihood that an exploit fails

Or further specialize:

- Mitigate a known vulnerability (repair or removal)

GI relies on test cases to ensure correctness.

Problem: What if tests suck?



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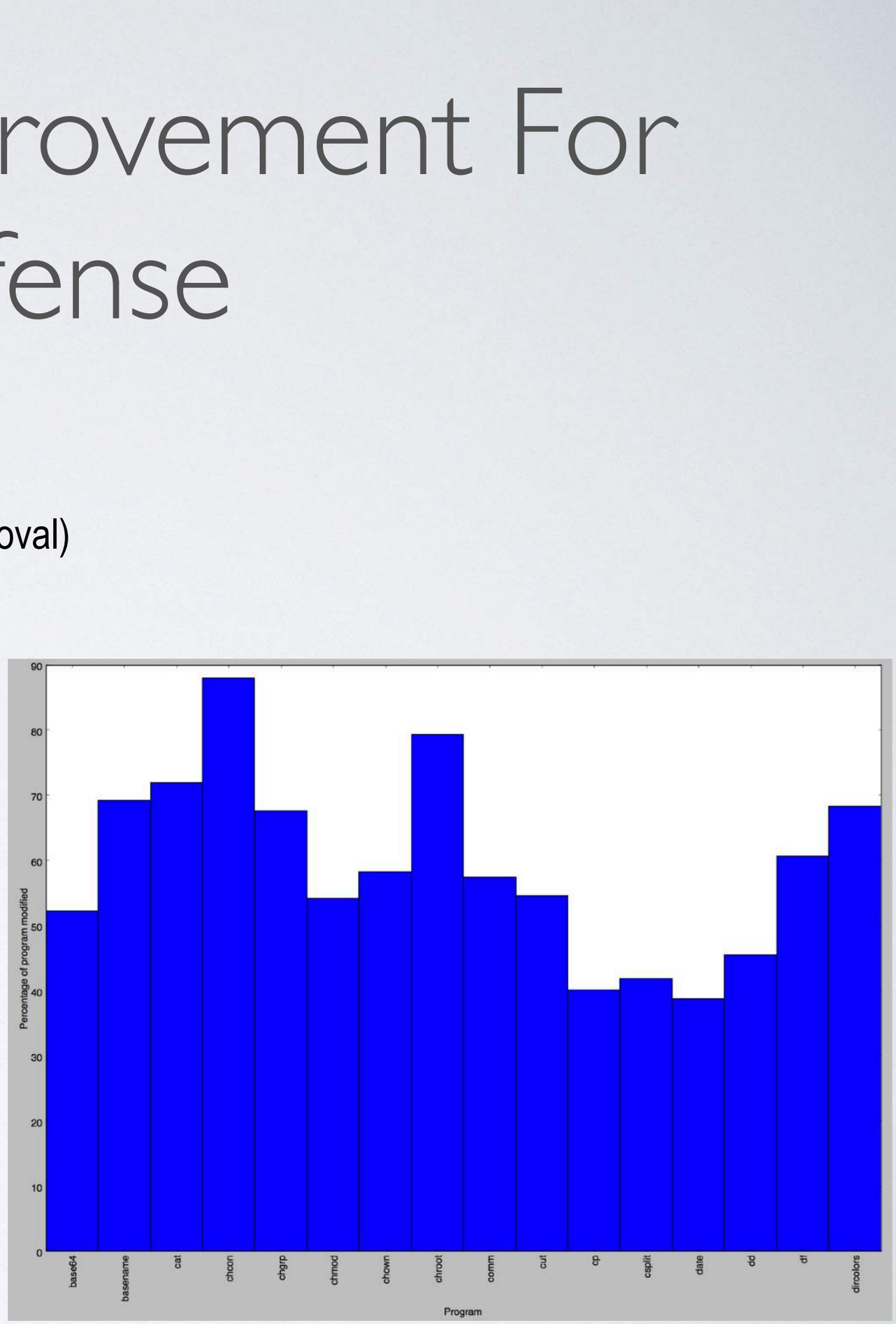

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***Solution:* Evolve better tests**

We need to go deeper

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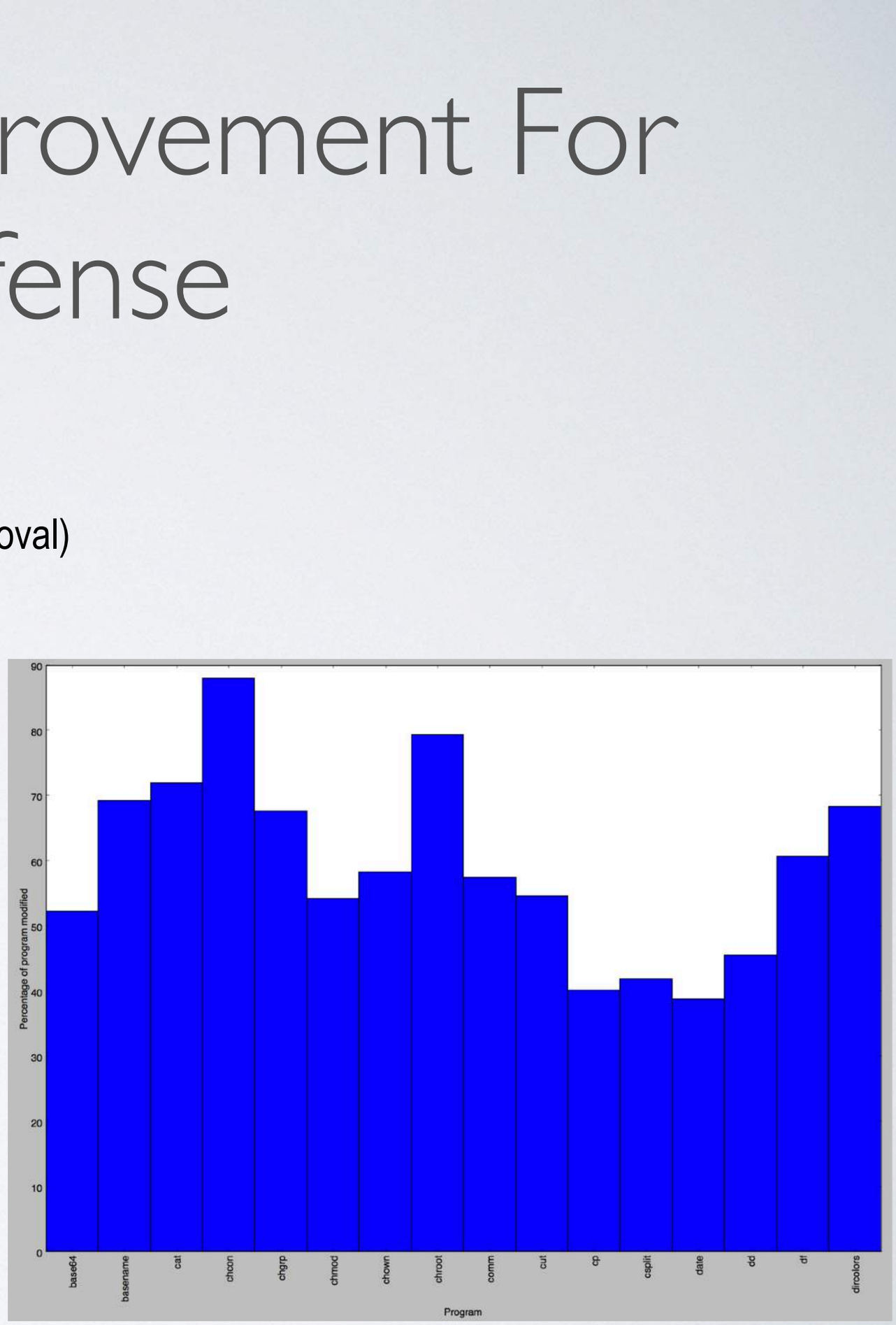

Fuzzing

Used to stress test software, typically using random or semi-random test data, to uncover issues which may not be revealed in other testing.

Very popular for vulnerability discovery.

- Bug bounties
- Computing resources cost decreasing
- Some care about security

Types Of Fuzzers

Blackbox

- Traditional type of fuzzer
- Supply inputs and observe output (usually crashes)

Whitebox

- Use program analysis
- Microsoft Sage — found ~1/3 of bugs during development of Windows 7

Greybox

- Uses instrumentation
- Less effective than whitebox fuzzing, but more efficient

Dumb

- Unaware of input format or protocol

Smart

- Aware of input format or protocol

Evolutionary Fuzzers

A recent trend which uses evolutionary computation to guide fuzzing.

Earliest known work is by Dr. Jared DeMott (2006) [1]

- Evolutionary Fuzzing System (EFS), built on General Purpose Fuzzer
- Evolutionary greybox fuzzer

American Fuzzy Lop (AFL) (2014) [2]

- Most well known evolutionary greybox fuzzer

Vuzzer (2017) [3]

- Application aware evolutionary greybox fuzzer using dynamic taint analysis

American Fuzzy Lop

A mutation-based dumb evolutionary greybox fuzzer.

Favors tests with crashes, more branches hit, and/or new execution paths.

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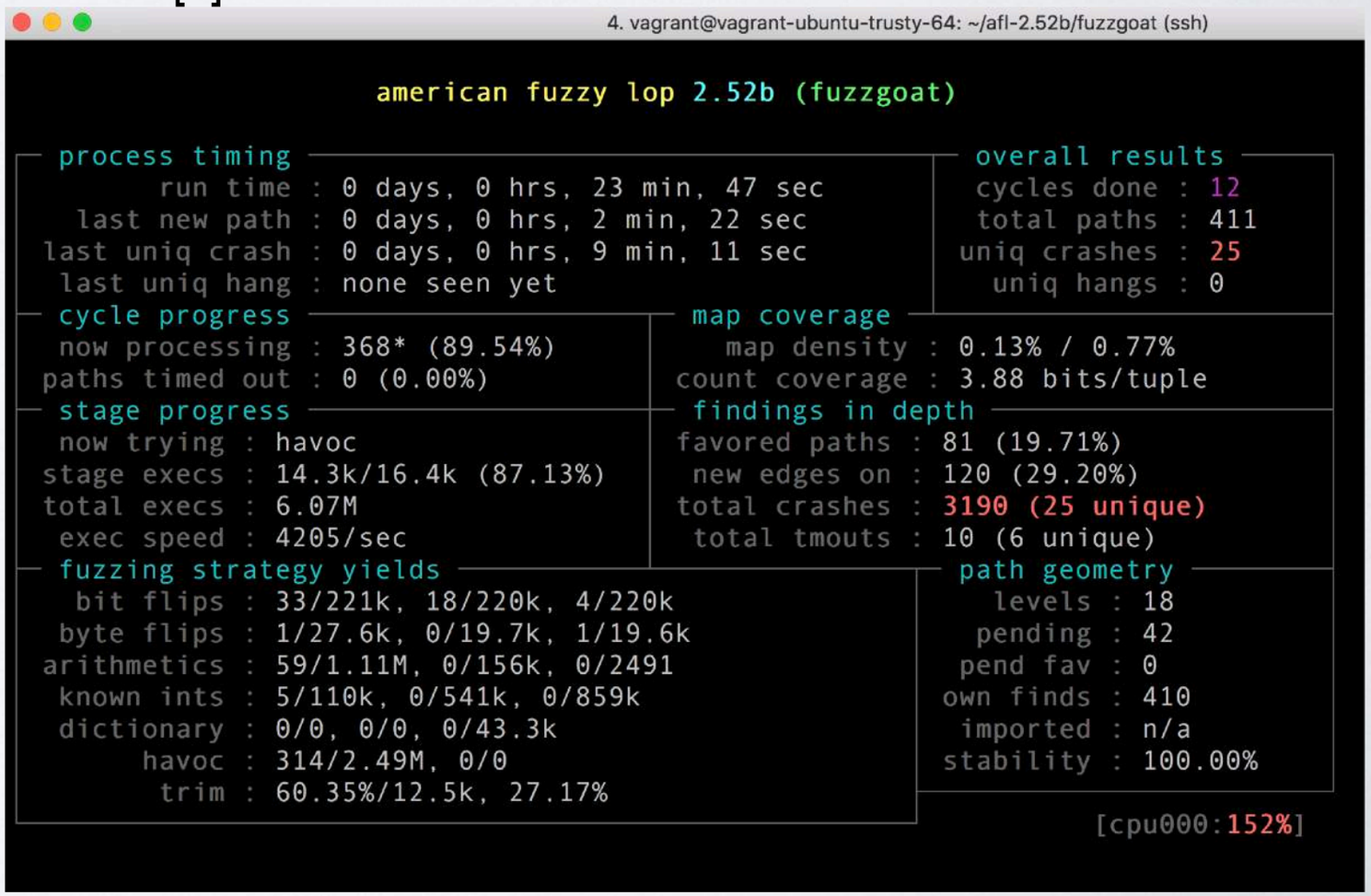
Number of notable vulnerabilities found: 371* [2]

Supports fuzzing binaries using QEMU

Forks:

- Kernel system calls [4]
- Virtual Machines [5]



Interesting Fuzzing Examples

Evolutionary fuzzers have been able to learn protocols and file formats.

EFS can learn protocols, such as SMTP, using a handful of protocol related strings. [6]

AFL was used to learn the JPEG file format [7]

- Started with a text file containing: “hello”
- Discovered jpeg header byte
- Generated a grayscale 3x784 pixel image
- Generated images with other patterns:

https://lcamtuf.blogspot.com/2014/11/pulling-jpegs-out-of-thin-air.html

Fuzzgoat [8]

A vulnerable C program, based on a JSON parser

Numerous memory corruption bugs

Starting seed for AFL: {“”:””}

With test seed: 29.4% code coverage (kcov)

After ~43 hours of fuzzing with AFL

- 67 unique crashes found
- 0 hangs
- 944 test cases queued

With 1,011 tests: 90.5% code coverage (kcov)

Example Evolved Test Cases

```
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Hunting And Fixing Bugs

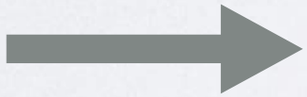
Fixing bugs in your sleep [9] application of dreaming device [10]

Online

By Pixabay. Public domain

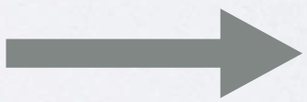
Offline

User generated bugs



Release

Validate



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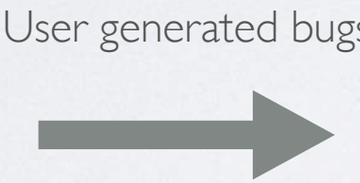

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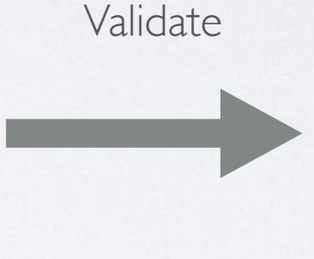

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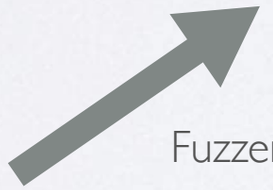

Fuzzer generated
Bugs

Hunting And Fixing Bugs

Fuzzers can help generate tests, but may be a useful component in automated bug fixing.

After ~43 hours of fuzzing fuzzgoat with AFL

- **67 unique crashes found**
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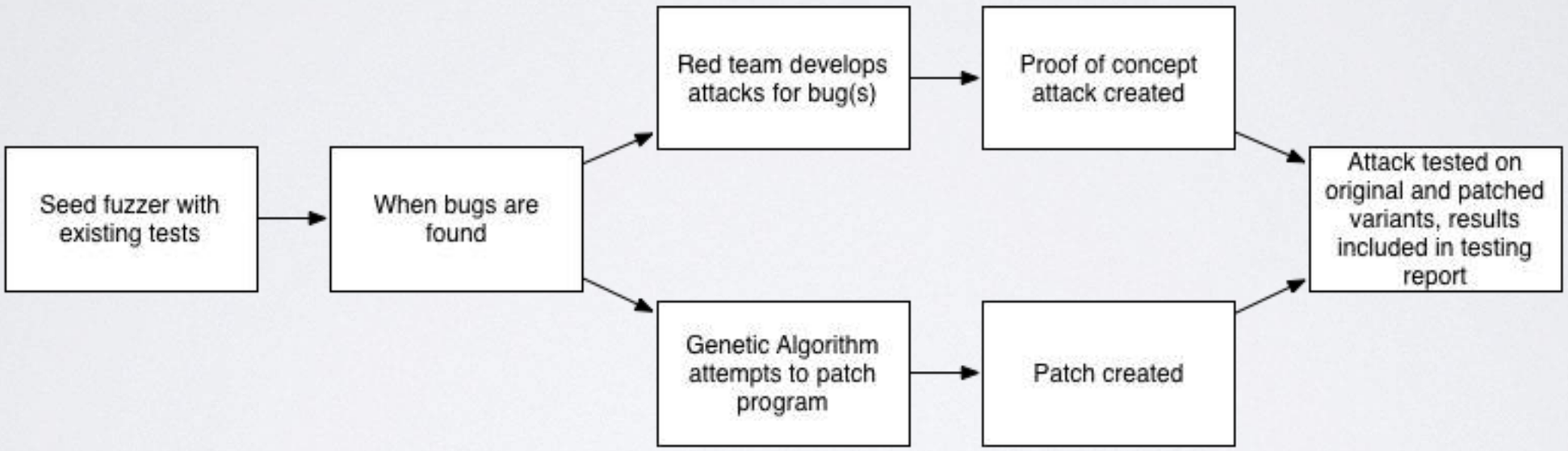
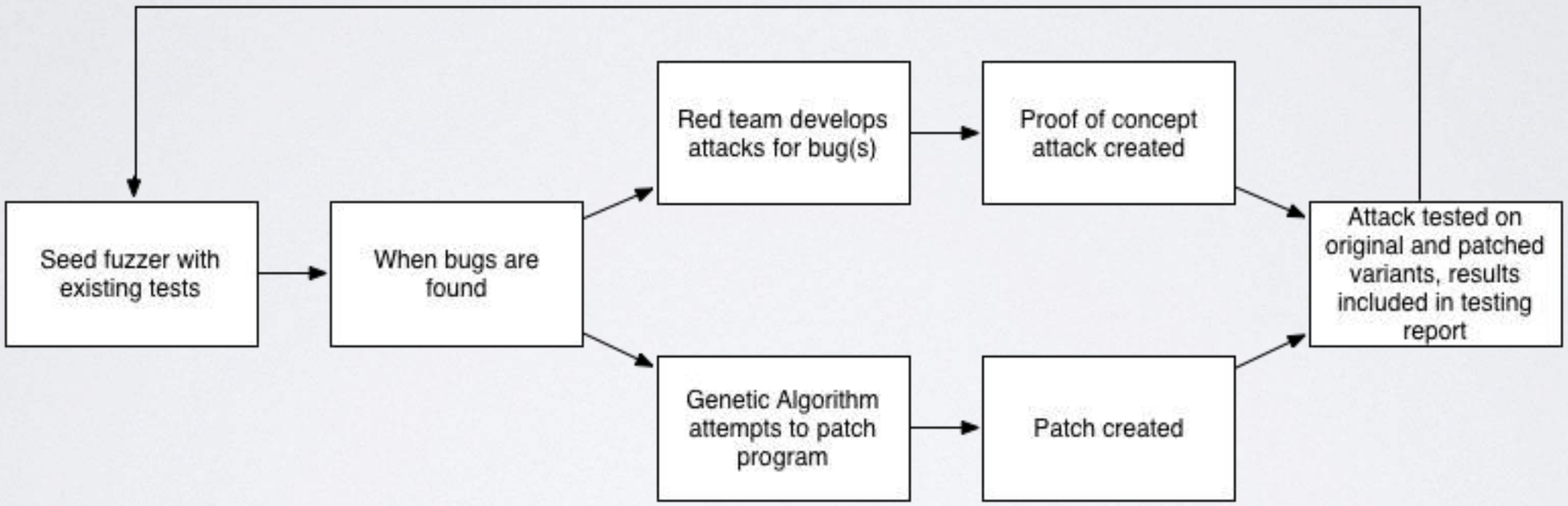
Treat crash test cases as bugs.

Incorporate return code (or lack of erroneous output) into fitness calculation.

Hunting And Fixing Bugs



Automated Hunting And Fixing Bugs



Genetic Improvement For Autonomic Computing

MAPE-K = Monitor Analyze Plan Execute over shared Knowledge

Enables self-* properties (self-configuration, self-healing, self-optimization, self-protection)

Autonomic system to tune and change GI parameters based on goals or priorities and system state.

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Questions?

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