Perun: Keep Your Project's Performance Under Control

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Motivation:
Why Care About Performance?

Performance is Important

- Software performance bugs are an omnipresent problem[1]:

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  → *hanging effectively forever* for large job batch.

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APACHE Spark

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stackoverflow

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  → *34 minutes long outage*.

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- Software performance bugs are an omnipresent problem[1]:
  - **Cluster computing engine** may *freeze* after an update!
  - **Cloud services** may *crash*!
  - **Parsers** may experience significant *slowdown*!

- An internal check for uniqueness
  → *hanging effectively forever* for large job batch.
- A regular expression for stripping whitespaces
  → *34 minutes long outage*.
- One of *Chrome*’s parsers
  → *noticeable slowdown* for long lines.

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- Godoc source code parsing
  → $\mathcal{O}(n^2)$ loop for Go structs definitions.

Recency is Important

- **Recency is important as well:** it pays off to discover bugs quickly.
  - Recently introduced bugs, as opposed to dormant bugs[2],
    - take on average less time to fix;
    - can be fixed by less experienced developers;
    - the fix is generally smaller.

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- However, what about performance bugs?
  - Most solutions are either ad-hoc or proprietary.
  - We are not aware of any **complex open-source** solutions.

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Meet Perun: Performance Version System

Perun[3] = Complex Solution for Performance Analysis and Testing

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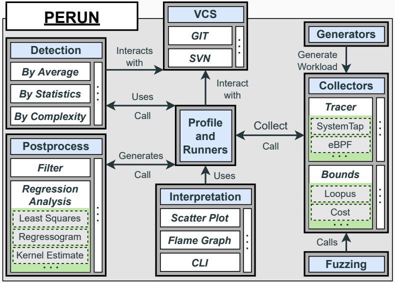

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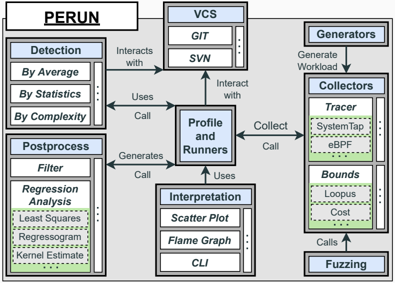

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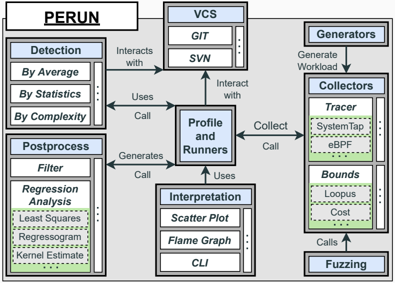

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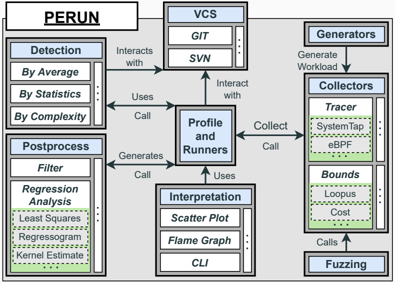

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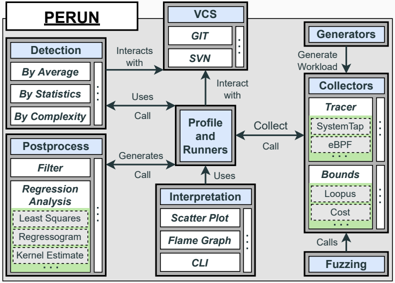

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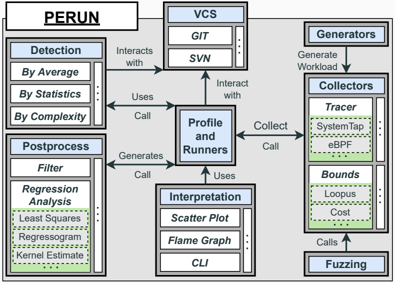

PERUN

Detection
By Average
By Statistics
By Complexity

Postprocess
Filter
Regression Analysis
Least Squares
Regressogram
Kernel Estimate

VCS
GIT
SVN

Interacts with
Uses
Call
Generates
Call
Interact with

Profile and Runners

Uses

Interpretation
Scatter Plot
Flame Graph
CLI

Generators
Generate Workload

Collectors
Tracer
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Collect
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Calls

Fuzzing

* Often the only thing done by traditional profilers.

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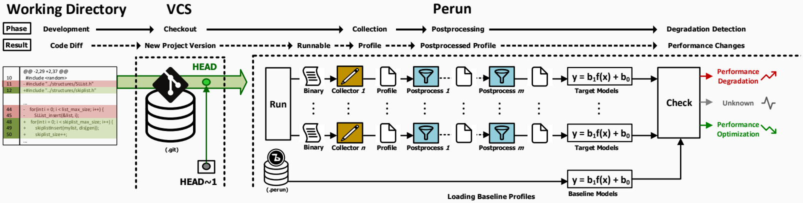
Perun Workflow: Overview



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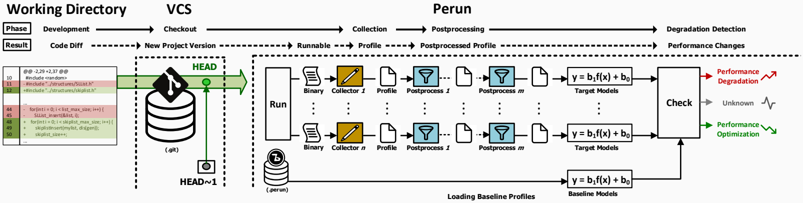

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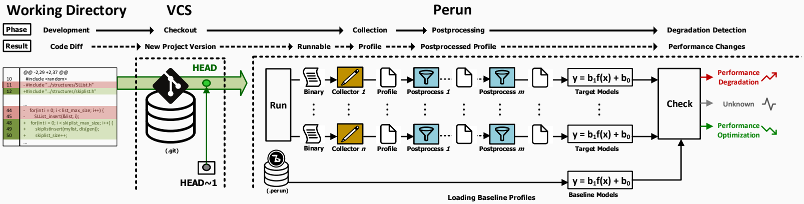

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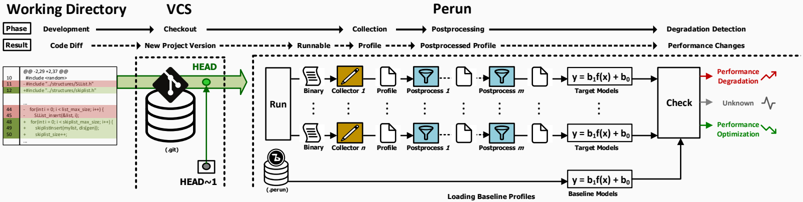

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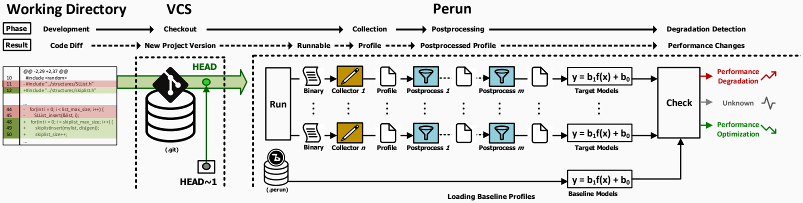

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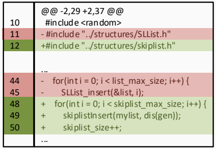
Perun Workflow: Repository

Working Directory

Phase **Development**

Result **Code Diff**



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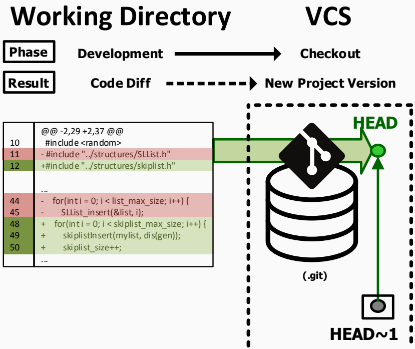

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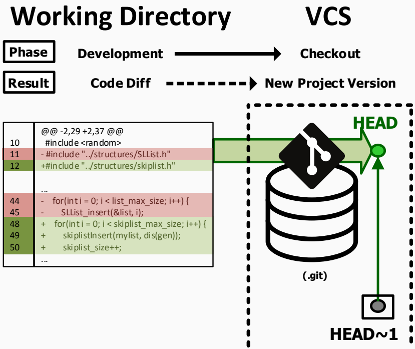

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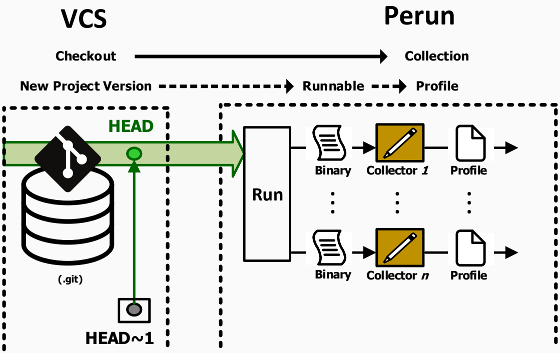
2. We initialize a **VCS** (e.g., Git) for project versioning.
3. We initialize **Perun** in the repository alongside the VCS.

Perun Workflow: Profiles



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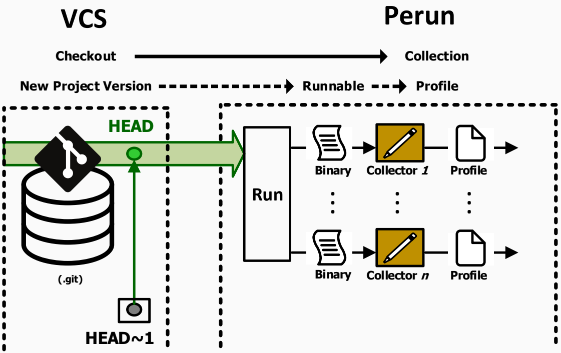

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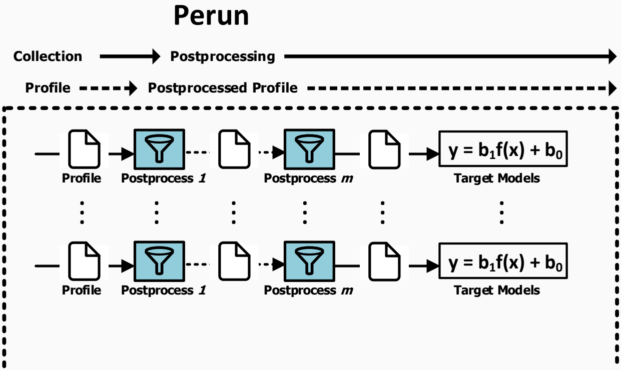

5. We create **performance models** from profiles using postprocessors.
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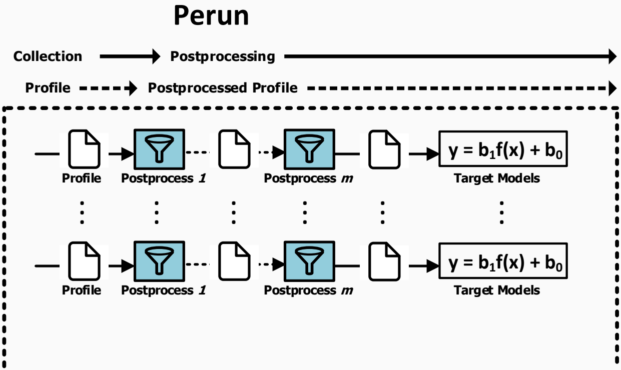

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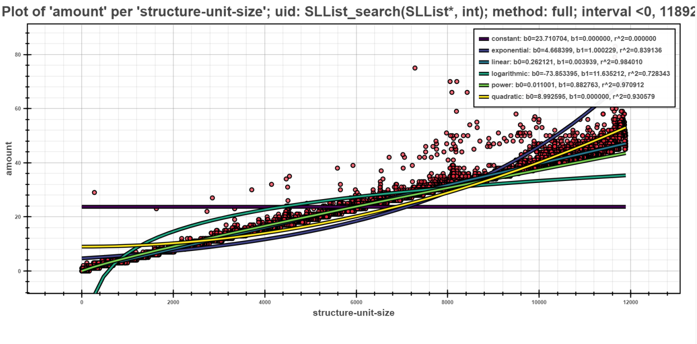

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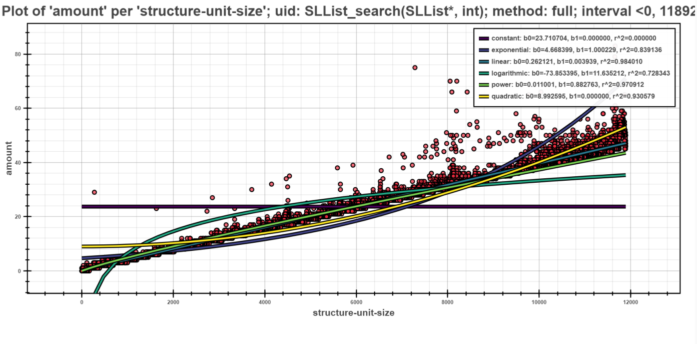

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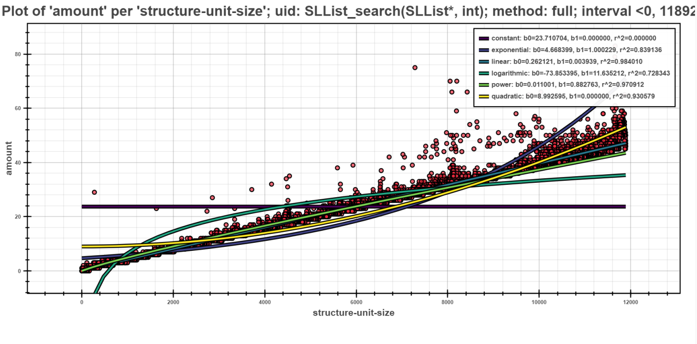

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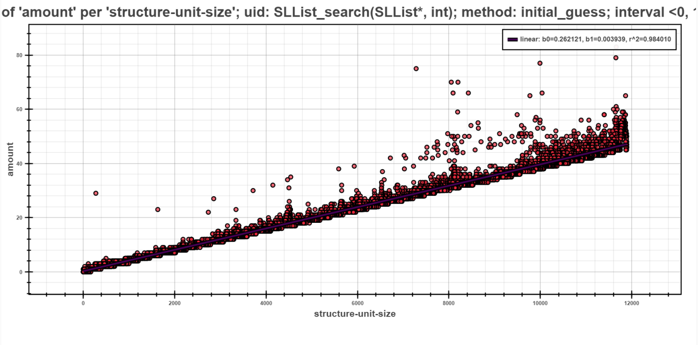

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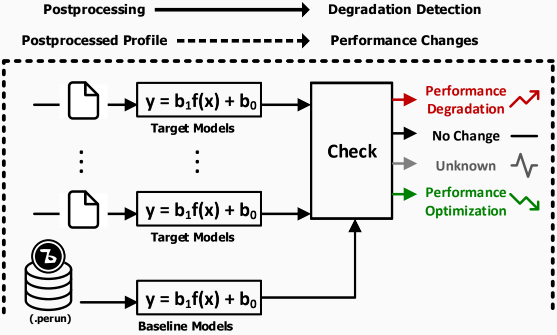

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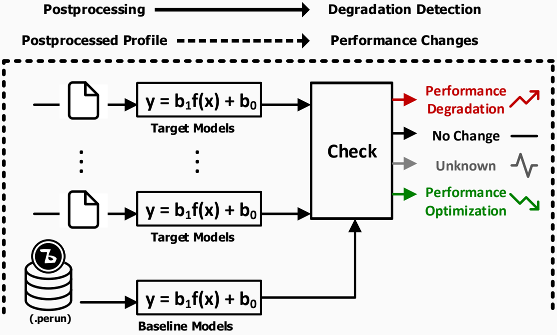

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    - Modified Z-score $y_i = \frac{x_i - \tilde{X}}{k \cdot median(|x_i - \tilde{X}|)}$
    - IQR multiple $Q_1 - k \cdot IQR < x < Q_3 + k \cdot IQR$

Perun Workflow: Detection Example

- Multiple **detection algorithms** are implemented in Perun:
  - *Best Model Order Equality*
  - *Integral Comparison*
  - . . .
  - *Exclusive-Time Outliers*

- **Exclusive-Time Outliers:**
  - Based on per-function comparison of exclusive-time **deltas** Δ.
    - *Exclusive-time (self)*: time spent exclusively in a function.
  - A hierarchy of outlier detection methods determines the **severity**:
    - Modified Z-score $y_i = \frac{x_i - \tilde{X}}{k \cdot median(|x_i - \tilde{X}|)}$
    - IQR multiple $Q_1 - k \cdot IQR < x < Q_3 + k \cdot IQR$
    - Standard deviation multiple $\overline{X} - k \cdot \sigma < x < \overline{X} - k \cdot \sigma$

Demonstration of Perun #1: Finding Performance Changes

CPython: Issue #92356

- **CPython**: Reference C implementation of a Python interpreter.

[4] Reported by user `mdboom`: `https://github.com/python/cpython/issues/92356`

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So problem solved. Why use Perun?

- Discovering the issue and finding the root cause is the hard part.
  - Often requires **significant** manual effort by the developers.
- **Perun** reduces this effort and helps the developers.
  - Perun utilizes the **recency** principle and results from past profiling.

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Using **Perun**, we could handle the **issue #92356** as follows:

1. We **initialize** a CPython repository with Perun.
2. We **store** a profile for CPython **v3.10.4** ctypes benchmark in Perun.
    - We denote this profile as baseline.
    - Perun handles the *profile-commit* link internally.

Perun commands

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perun collect -c <py3.11.0a7> -a <benchmark> trace -b <files>
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perun add <target>
perun check -f profiles <baseline> <target>
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4. We **profile** the ctypes benchmark for CPython **v3.11.0a7**.
    - We denote the resulting profile as target.
5. We **compare** the baseline and target profiles.
    - Perun supports multiple comparison algorithms.
    - For this particular issue, we used *Exclusive-Time Outliers*.

Perun commands

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perun collect -c <py3.11.0a7> -a <benchmark> trace -b <files>
perun add <target>
perun check -f profiles <baseline> <target>
```

CPython: Regression Detected

Location	Result	TΔ [ms]	TΔ [%]
_ctypes_init_fielddesc	NotInBaseline	77.95	5.23
_ctypes_get_fielddesc	SevereDegradation	52.9	3.55
_ctypes_callproc	Degradation	2.84	0.19
...			
_ctypes.cpython-311	TotalDegradation	136.92	9.19

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* TΔ: exclusive-time delta of *target* − *baseline*.

- **Root cause** of the issue: repeated calls of an init function.

Function `_ctypes_get_fielddesc`

```
if (!initialized) {
    _ctypes_init_fielddesc();
}
```

CPython: Hotfix

6. We **create** a new hotfix branch and **fix** the issue.

Fixing `_ctypes_get_fielddesc`

```
  if (!initialized) {
+     initialized = 1;
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  }
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Perun commands

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perun collect -c <py3.11.0a7-fix> -a <benchmark> trace <...>
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- The **_ctypes_get_fielddesc** Δ has improved significantly.

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⇒ Perun leverages **VCS** and **Recency** to successfully discover and help locate performance issues in new project versions.

Demonstration of Perun #2: Generating Workloads

Stack Overflow: Issue

- Recall the **Stack Overflow** issue:

stackoverflow

- A regular expression for stripping whitespaces → *34 minutes long outage*.

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Perun's Performance Fuzzing![5]

[5] Builds on a principle originally proposed by C. Lemieux et al.: *PerfFuzz: automatically generating pathological inputs.*

Stack Overflow: Introducing Fuzzing

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    - The program is not monitored for errors or crashes, but **slowdown**.
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  - The program is not monitored for errors or crashes, but **slowdown**.
  - We evaluate the results using profiling.
  - **The goal** is to find inputs that cause severe slowdown[7].

[6] M. Liscinsky: *Fuzz Testing of Program Performance*.

[7] In some of our experiments, Perun's Fuzzer achieved a **slowdown of several hours**!

Stack Overflow: Fuzzing Setup

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  - **Perun's own mutation rules.** Particularly useful rule is:
    - `T.10`: Insert whitespaces to a random position in a string.
  - **Size limits:** (a) 5 000 bytes, (b) 10 000 bytes.

Stack Overflow: Fuzzing Results

Input	Size [B]	Lines	Whitespaces	Duration [s]	Slowdown
seed	3535	150	306	0.096	–
worst-case$_a$	5000	5	4881	1.566	16.3x
worst-case$_b$	10000	17	9603	2.611	27.2x

⋆ We let the fuzzing run for several hours to obtain the shown workloads.

⋆ The generated workloads can then be used for future performance testing.

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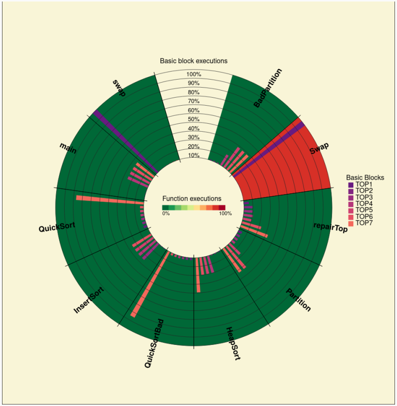
- We employ different **mutation strategies** based on the input type.
  - Text files, binary files, domain-specific (e.g., XML), . . .

Ongoing and Future Work

Ongoing Work: Granularity

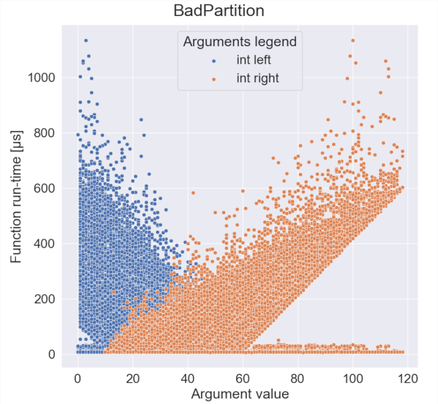
- We focus on increasing profiling **granularity**.
    - Measuring time spent per function basic block[8].



[8] P. Mocary: *Performance Analysis of Programs Based on PIN Framework*.

Ongoing Work: Precision

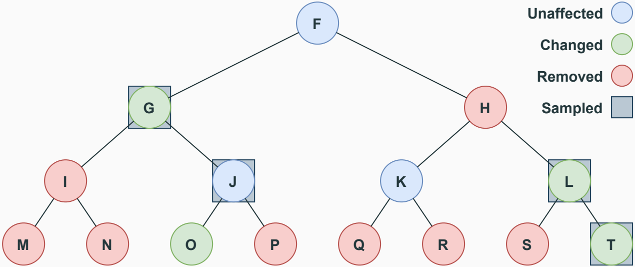
- Moreover, we focus on increasing profiling **precision**.
  - Measuring time spent w.r.t. function parameter values[9].



[9] P. Mocary: *Performance Analysis of Programs Based on PIN Framework*.

Ongoing Work: Efficiency

- Finally, we focus on increasing profiling **efficiency**.
  - Utilizing a collection of heuristics to speed up the profiling[10].
  - We propose to select and sample particularly **important** functions.



[10] J. Pavela: *Efficient Techniques for Program Performance Analysis*.

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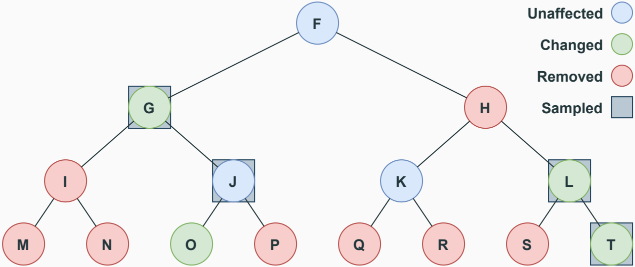

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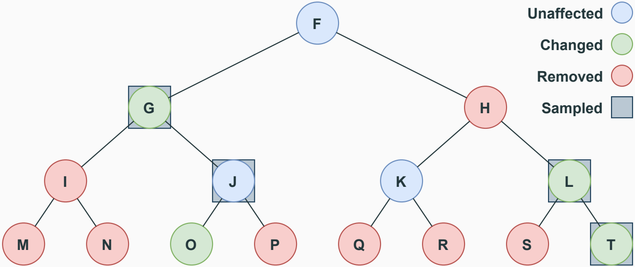

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  ⇒ Fully profiling all the important functions.

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- **Ongoing and Future work:**
  - Improving **granularity**, **precision** and **efficiency** of profiling.
  - Support for more **languages**, performance **metrics**, existing **tools**.

Perun: Keep Your Project's Performance Under Control

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