Soundy Automated Parallelization of Test Execution

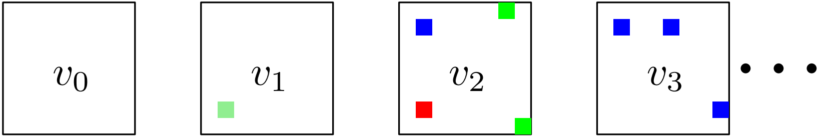
Shouvick Mondal, Denini Silva, Marcelo d'Amorim

IIT Madras (India), UFPE (Brazil), UFPE (Brazil)

ICSME 2021 (Virtual Event)

September 27 – October 1

Context: software evolution and regression testing



Regression testing: testing software changes for regression bugs.

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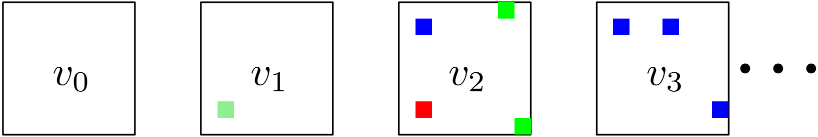

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Existing solutions

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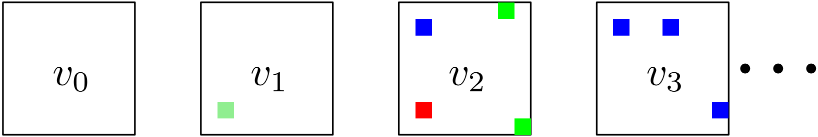

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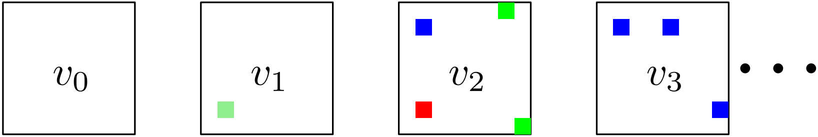

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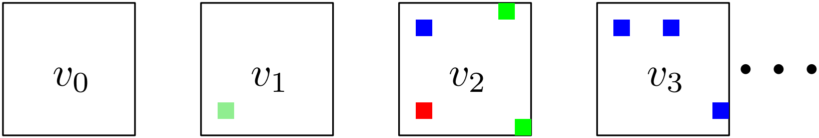

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Test execution parallelization (*is less explored*...).[4]

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[4] **Source**: J. Candido et al., *Test suite parallelization in open-source projects: A study on its usage and impact.*, ASE 2017.

Two issues in test parallelization

Test dependencies and **data races** give rise to **test flakiness**.

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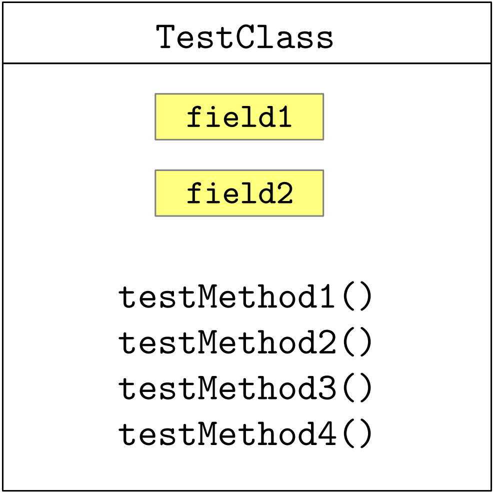

TestClass

field1

field2

testMethod1()
testMethod2()
testMethod3()
testMethod4()

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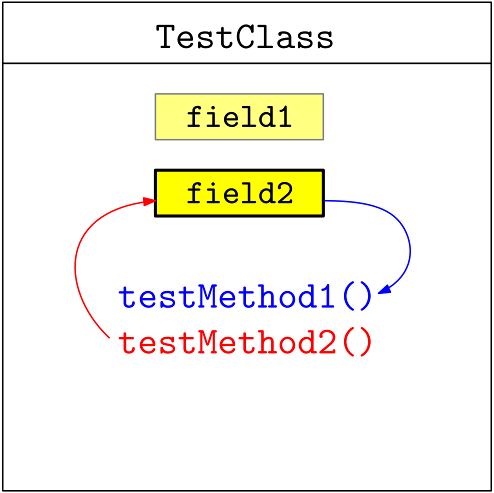

Dependencies: $\{t_1 \to t_2\}$

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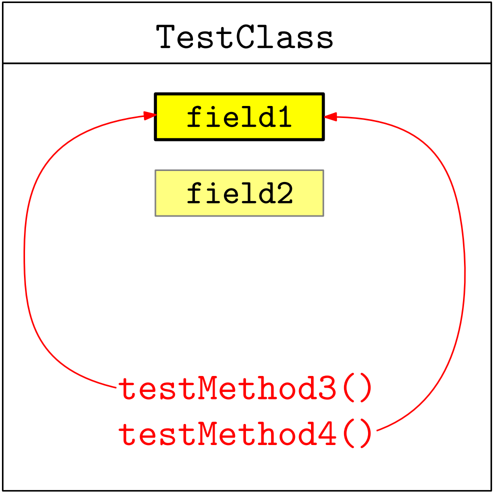
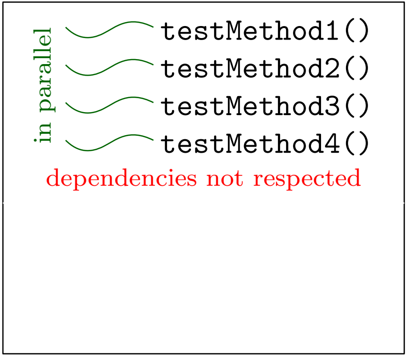


Dependencies: $\{t_4 \rightarrow t_3\}$

Two issues in test parallelization

Test dependencies and **data races** give rise to **test flakiness**.

$$\{t_1 \rightarrow t_2,\ t_4 \rightarrow t_3\}$$



Run 1:	P	P	P	P
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Run 3:	F	F	P	P
Run 4:	P	P	F	P
Run 5:	F	P	P	F

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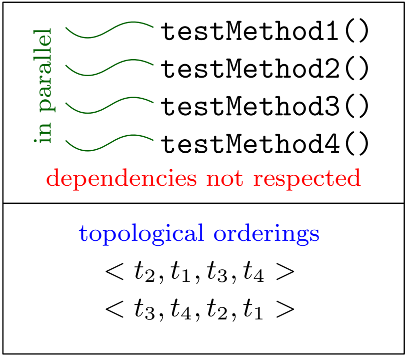

in parallel

testMethod1()

testMethod2()

testMethod3()

testMethod4()

dependencies not respected

topological orderings

$< t_2, t_1, t_3, t_4 >$

$< t_3, t_4, t_2, t_1 >$

Run 1:	P	P	P	P
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A topological sort would reveal a **safe** execution sequence.

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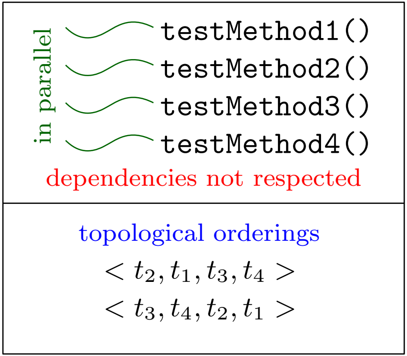

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A topological sort would reveal a **safe** execution sequence.
But **prerequisite** is *test dependency detection*!

Performance of a test dependency detector

State-of-the-art tool: PRADET (ICST 2018)

PRADET

Step 1 (costs *x*): Sequential execution

Performance of a test dependency detector

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PRADET

Step 1 (costs x): Sequential execution
Step 2 (costs y): Dynamic data-flow analysis
Step 3 (costs z): Dependency refinement

The overhead of PRADET was **substantially higher than sequential execution itself** ($y + z > x$).
NOT practical *to use PRADET* to aid test parallelization!

Our approach: **PASTE**

PArallel-**S**equential **T**est **E**xecution

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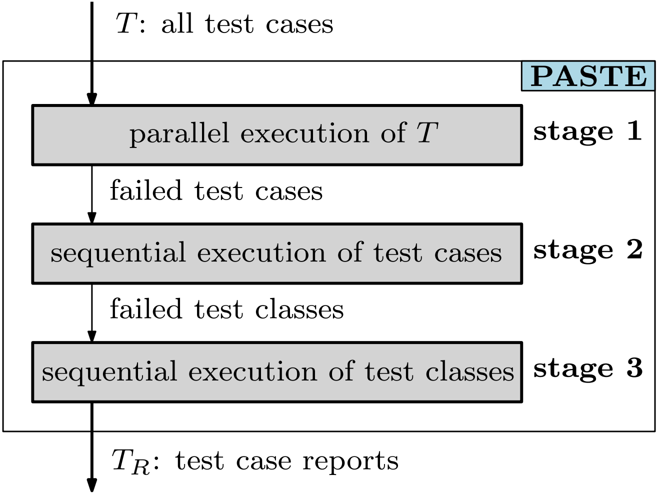
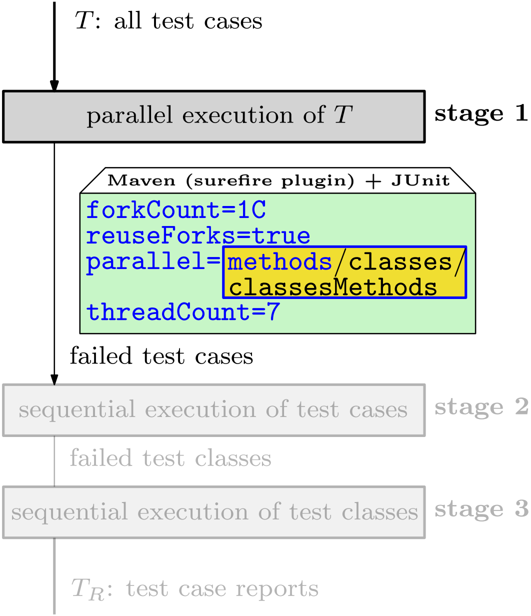


Stage 1: parallel execution



T: all test cases
parallel execution of T
stage 1
Maven (surefire plugin) + JUnit
failed test cases
sequential execution of test cases
stage 2
failed test classes
sequential execution of test classes
stage 3
T_R: test case reports

```
forkCount=1C
reuseForks=true
parallel=methods/classes/
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threadCount=7
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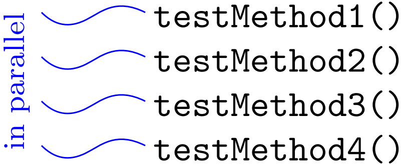
Stage 1: parallel execution



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$$\{t_1 \rightarrow t_2,\ t_4 \rightarrow t_3\}$$

Execute the four test methods **in parallel**.

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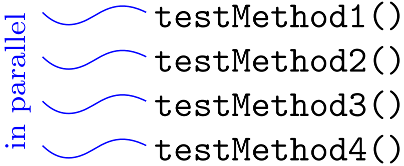

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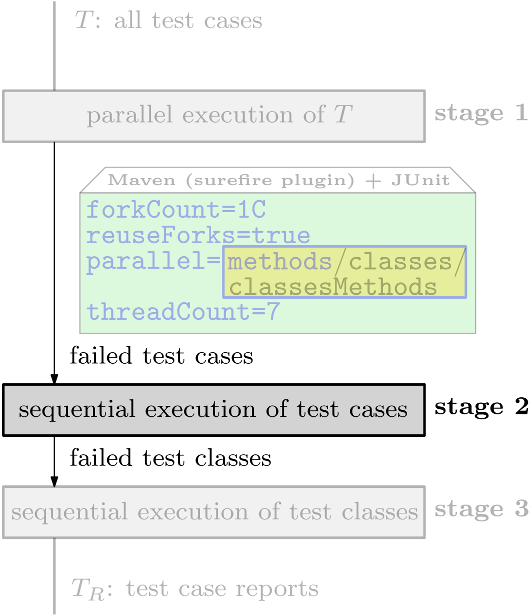
Execute the four test methods **in parallel**.
Some test cases may fail!

Stage 2: sequential re-execution of failed test cases



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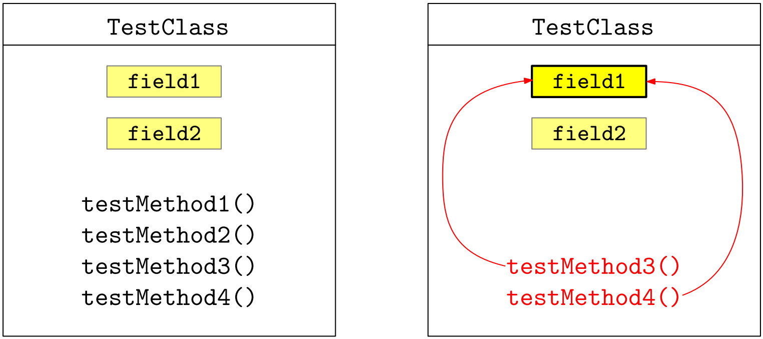

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Handle flakiness through **sequential** **re-execution** of **test cases** (*to circumvent **data races***).

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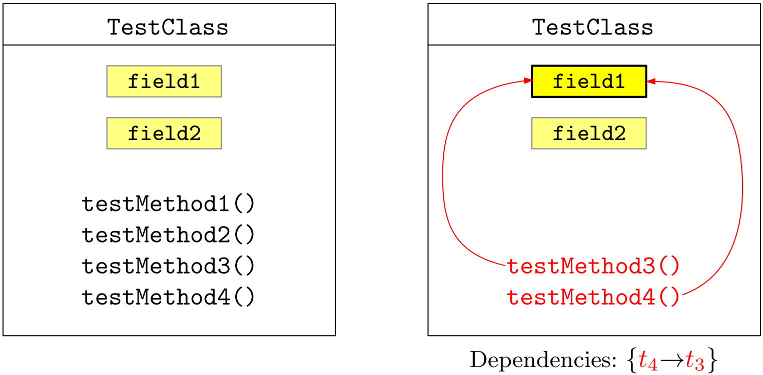

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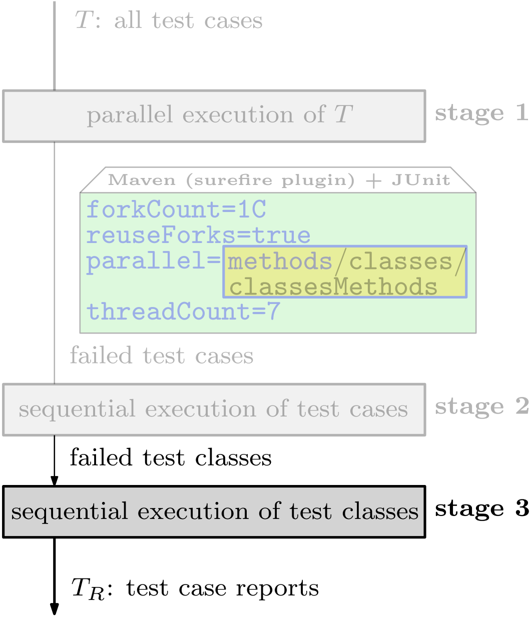
Handle flakiness through **sequential** **re-execution** of **test cases** (*to circumvent* ***data races***).

Some test cases may fail ***again***!
Track their test class names.

Stage 3: sequential re-execution of failed test classes



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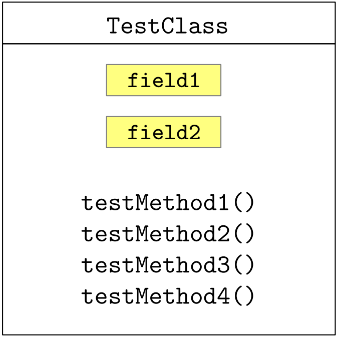
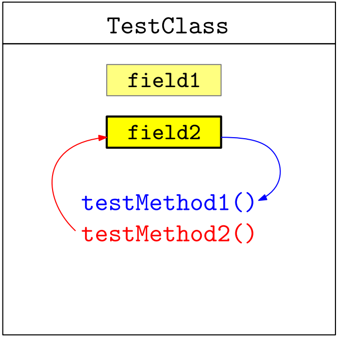
Stage 3: sequential re-execution of failed test classes

Handle flakiness through **sequential re-execution** of **test classes** (*to circumvent **broken test dependencies***).





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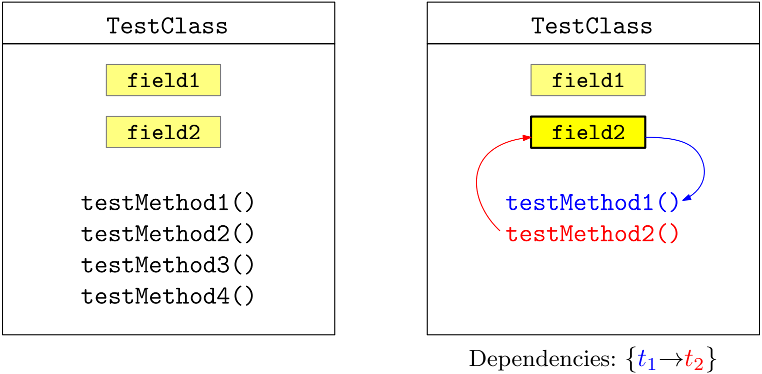
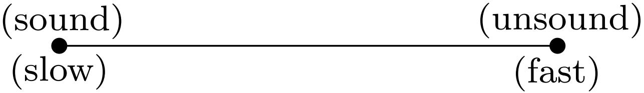


PASTE builds on the observation:
broken test dependencies that are manifested in parallel runs ***involve test cases from the same test class***.

The spectrum of soundness in parallelization

Sound: time invariant verdicts agree with sequential execution.



(sound)

(slow)

(unsound)

(fast)

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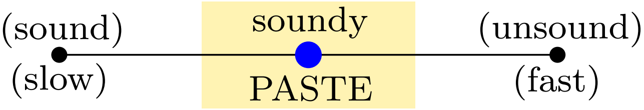

PASTE does not provide the soundness guarantee but is reasonable enough to yield end-to-end acceleration!

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No failures: Reran each test suite 10 times to **identify** and **eliminate tests failing** due to **non-determinism**.

Research Questions

RQ1 (feasibility #1)

Is it feasible to use parallelization options provided by the build system "out of the box" to run test suites?

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In 44% of the projects, no parallel configurations enabled a clean execution. Searching for the **parallel configuration for a clean execution is INFEASIBLE in general**.

RQ2 (feasibility #2)

Is it practical to use a test dependency analyzer to partition test sets as to enable sound parallel execution?

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Is it practical to use a test dependency analyzer to partition test sets as to enable sound parallel execution?

The runtime overhead of PRADET was substantially higher than that of the sequential execution itself. **NOT PRACTICAL to use PRADET to aid test parallelization**.

RQ3 (effectiveness #1)

How reliable is* PASTE *?

RQ3 (effectiveness #1)

How reliable is **PASTE** ***?***

Effective to circumvent the test flakiness provoked by test parallelization. There were **no cases of provoked failure that "survived" the third stage** of PASTE.

RQ4 (effectiveness #2)

What are the speedups obtained with* PASTE*?

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We observed speedups in 52% of the projects. The **configuration `classes`** performed the best: **median 1.59x** (best: 2.28x, average: 1.47x, worst: 0.93x).

Related Work

Most relevant related work

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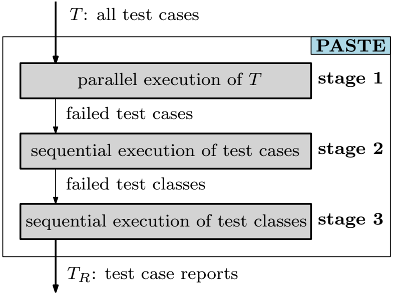
TEDD–FSE 2019	NLP-based web test dependency detector tracks client-server network operations.	Domain specific Yet to explore

Conclusions

We discussed **PASTE**, a lightweight approach to parallelize execution of test suites through the sequential re-execution of *test cases* (*to avoid data races*) and the sequential re-execution of *test classes* (*to avoid broken test dependencies*).



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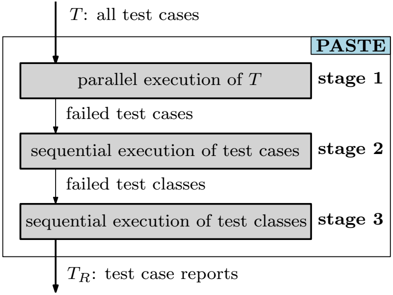

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PASTE

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failed test cases

sequential execution of test cases — **stage 2**

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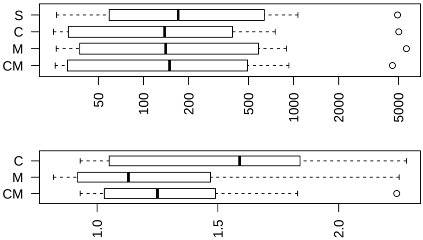

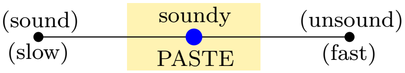

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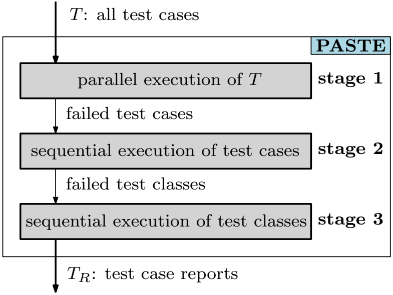

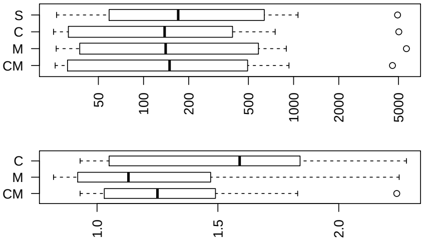

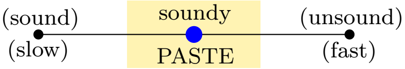

Thank You

Artifacts: `https://github.com/STAR-RG/paste`