

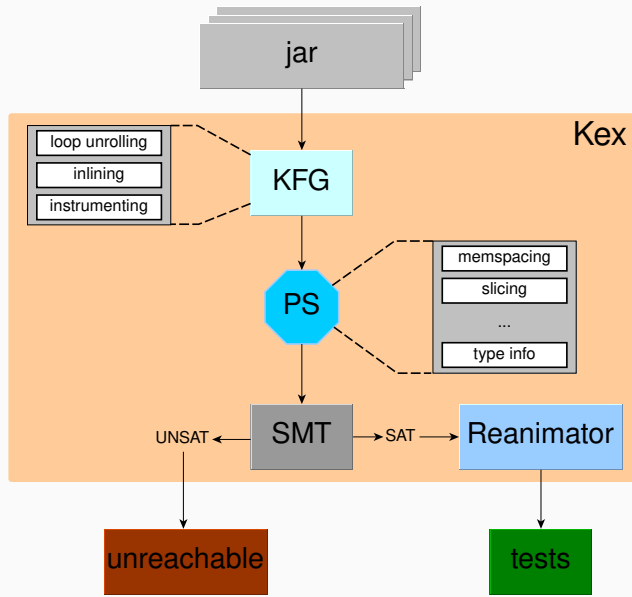
Kex in 2021: Ups and Downs

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December 18, 2021

- white box fuzzer for JVM bytecode
- based on symbolic execution
- test generation for Java and Kotlin

Kex overview



What happened in 2021

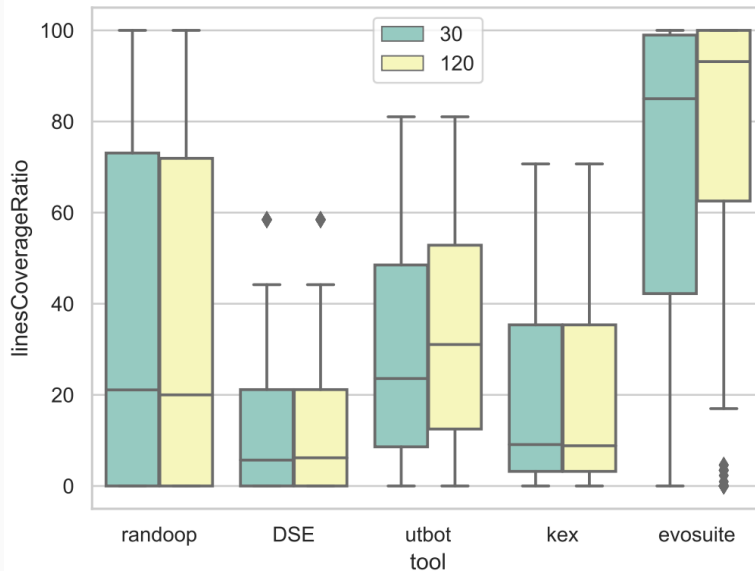
- participation in SBST Java tool competition 2021¹
- improvement of Java standard library support
- evaluation of Reanimator

¹Panichella S. et al. Sbst tool competition 2021 //2021 IEEE/ACM 14th International Workshop on Search-Based Software Testing (SBST). – IEEE, 2021

Automatic test case generation competition

- 6 test projects with 98 benchmarks
- 30 and 120 second time budgets
- 4 participating tools and 1 baseline

SBST 2021 results



SBST 2021: Kex results²

- Kex was ranked fifth with score of 44.21
- Kex achieved any coverage only on one project
 - average coverage of ~20%
- Kex failed on 5 out of 6 projects
 - 1 project failed because of unhandled ASM error
 - 2 projects failed because Kfg encountered some unexpected bytecode
 - 2 projects failed because Kex required too much RAM
- Kex (and Reanimator) failed on some of the more complex language features (abstract classes, inner classes, etc.)
- Kex required too much of disk space

Main teakeaway: Kex had a low level of maturity

²Abdullin A., Akhin M., Belyaev M. Kex at the 2021 SBST Tool Competition //2021 IEEE/ACM 14th International Workshop on Search-Based Software Testing (SBST). – IEEE, 2021

SBST 2021: implications

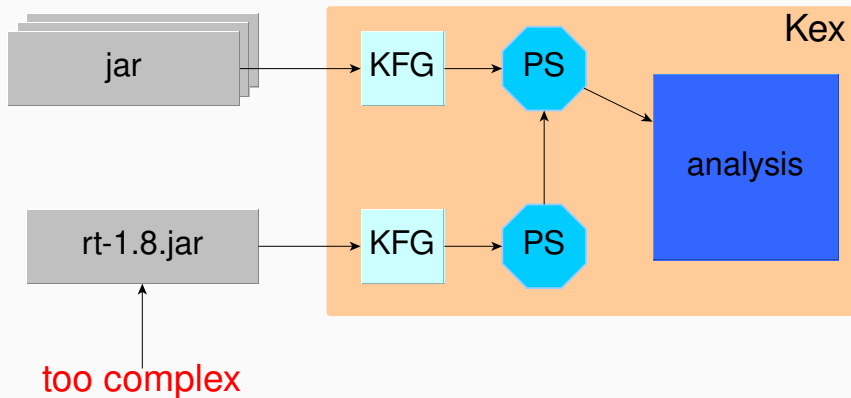
- Kfg was fixed and (hopefully) became more stable
- Kfg and Kex were optimized w.r.t. RAM usage:
 - Kfg currently uses ~2 times less RAM
 - Kex uses Kfg more optimally
- Kex and Reanimator were extended to support some new language features

| | 30s | 120s |
|-----------------|------------|-------------|
| line coverage | 22.31% | 26.70% |
| branch coverage | 14.69% | 17.95% |

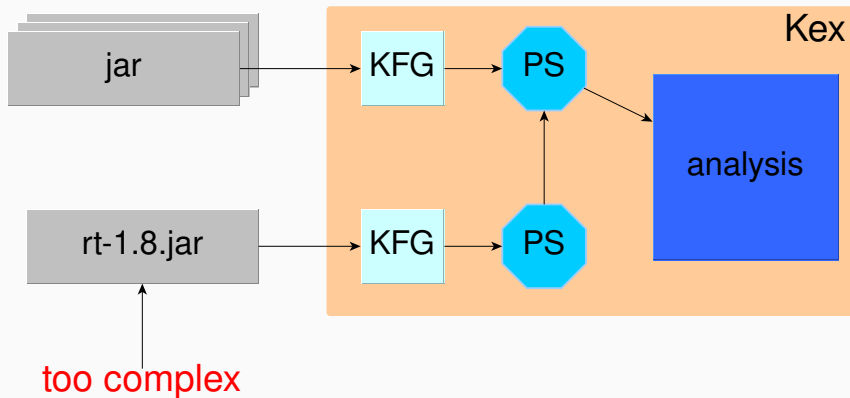
Applied for SBST 2022 competition



Java standard library support at the end of 2020



Java standard library support at the end of 2020



Many of the standard library classes can be approximated

Prototype implementation based on `kex-intrinsics`³:

- wrappers for primitive types
- string builders
- some collections (based on `ArrayList` approximation)
- utility methods from `Arrays` and `System` classes

Kex substitutes all Java runtime operations with approximated analogs if they are available

³<https://github.com/vorpai-research/kex-intrinsics>

Exmample of ArrayList::add method

```
@Override
public boolean add(E e) {
    AssertIntrinsics.kexNotNull(elementData);
    int oldLength = elementData.length;
    elementData = CollectionIntrinsics.generateObjectArray(
        oldLength + 1,
        index -> {
            if (index < oldLength) return elementData[index];
            else return null;
        }
    );
    elementData[oldLength] = e;
    return true;
}
```

Support of intrinsics

Predicate State level support:

- Kfg extended to support `invokedynamic`
- PS extended to support lambdas
 - lambdas can't change program state

SMT level support:

- slightly reworked memory model
 - arrays are now represented as SMT arrays
- \exists and \forall quantors for array operations
- λ expressions for array generation
- experimented with SMT string theory (unsuccessfully)

Java standard library support: current state

- prototype implementation
 - limited in expressiveness
 - limited number of supported classes
- no thorough evaluation
 - experiments show a small increase in coverage



- an approach to generate valid code snippets using only public API
 - can't produce invalid objects
- works in reasonable time
- applicable in any automatic test generation tool
- can be used in any programming language

Reanimator at the end of 2020

- working prototype
- evaluation:
 - testing with Kex on open source projects from github
 - testing on random objects
- can successfully and efficiently generate 70% of target objects on average

Problem: evaluation is not representative enough

- integrated Reanimator as an optional test generation module in Tardis⁴
 - extended Tardis model computation
- compared with its default test generator — Evosuite⁵
- used SBST 2021 benchmark for evaluation, but extended time budgets

⁴Braione P., Denaro G. SUSHI and TARDIS at the SBST2019 Tool Competition //2019 IEEE/ACM 12th International Workshop on Search-Based Software Testing (SBST). – IEEE, 2019

⁵Fraser G., Arcuri A. Evosuite: automatic test suite generation for object-oriented software //Proceedings of the 19th ACM SIGSOFT symposium. – 2011

Reanimator: current state

| | 60s | 120s | 300s | 600s |
|---------------------|--------|--------|--------|--------|
| tardis + evosuite | 13.96% | 15.71% | 18.50% | 19.60% |
| tardis + reanimator | 13.84% | 15.99% | 17.84% | 19.30% |
| kex + reanimator | 24.57% | 25.29% | 25.43% | 27.61% |

Reanimator: what to do

- implement Tardis approach in Kex
- compare both Tardis and Reanimator on random object generation
- improve Reanimator (duh)

Plans for the (nearest) future

- SBST 2022
- finish work on Reanimator
 - evaluation and publication
 - integrate Reanimator with concolic mode
- extend standard library support
 - support of state changes in lambdas
 - more classes

Contact information

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reposotory:

- <https://github.com/vorpal-research/kex>

