Kex at SBFT 2023 Tool Competition

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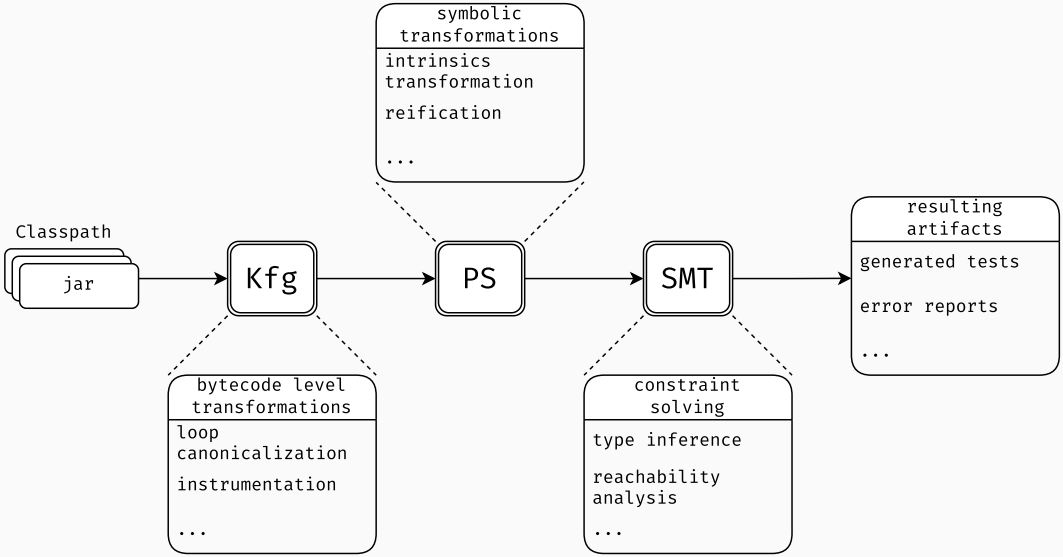
Kex[1]

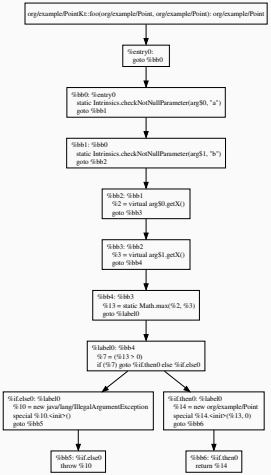
- a platform for analysis of JVM programs
  - mainly focused on automatic test generation
- based on symbolic execution
  - also has a concolic execution engine
- research prototype, under development
- third time participation in SBST/SBFT tool competition

[1] Azat Abdullin and Vladimir Itsykson. 2022. Kex: A platform for analysis of JVM programs. Information and Control Systems 1 (2022), 30–43. http://www.ius.ru/index.php/ius/article/view/15201

Kex overiview



Kfg[2]: CFG for JVM bytecode



- class management
- CFG in SSA form
- bytecode analysis and transformation

[2] https://github.com/vorpal-research/kfg

Predicate state: IR for symbolic transformations

```
(
  @S kotlin/jvm/internal/Intrinsics.checkNotNullParameter(arg$0, 'a')
  @S kotlin/jvm/internal/Intrinsics.checkNotNullParameter(arg$1, 'b')
  @S term166 = *(arg$0.x)
  @S term355 = *(arg$1.x)
  @S term587 = term166 < term355
  @S term1050 = term355 > 0
  @S term1368 = new java/lang/IllegalArgumentException
  @S throw term1368
) -> (
  @P arg$0 == null = false
  @P arg$0 instanceof org/example/Point = true
  @P arg$1 == null = false
  @P arg$1 instanceof org/example/Point = true
  @P term587 = true
  @P term1050 = false
)
```

- symbolic representation of a program
- SMT-specific transformations

Constraint solving

- PS allows support of multiple “backend” solvers
  - Z3, Boolector, CVC4, KSMT
- SBFT configuration used KSMT[3]
  - efficient asyncronos API for Z3 solver

[3] https://github.com/UnitTestBot/ksmt

JUnit test case generation

```
public class ArrayListValuedHashMap-init-90775276022 {
    Object term22200;
    // number of utility methods here
    // ...
    @Before
    public void setup() throws Throwable {
        try {;
            Object term22072 = newInstance(Class.forName("org.apache.commons.collections4.multimap.ArrayListValuedHashMap"));
            HashMap term22248 = new HashMap();
            term22200 = newInstance(Class.forName("org.apache.commons.collections4.multimap.HashSetValuedHashMap"));
            setField(term22200, term22200.getClass(), "map", term22248);
        } catch (Throwable e) {};
    }
    @Test
    public void test() throws Throwable {
        try {;
            Class<?> klass = Class.forName("org.apache.commons.collections4.multimap.ArrayListValuedHashMap");
            Class<?>[] argTypes = new Class<?>[1];
            argTypes[0] = Class.forName("org.apache.commons.collections4.MultiValuedMap");
            Object[] args = new Object[1];
            args[0] = term22200;
            callConstructor(klass, argTypes, args);
        } catch (Throwable e) {};
    }
};
```

Kex-rt[4]: Java standard library approximations

- approximations for standard library of Java 8
- simplifies the semantics of standard library classes
- contains approximations for
  - collections
  - primitive type wrappers
  - string buffers
  - etc.

[4] https://github.com/AbdullinAM/kex-rt

Kex-symbolic[5]

- traditional symbolic execution engine for automatic test generation
- traverses the CFG of PUT on a basic block level
- uses breadth-first search for path selection
    - proof-of-concept prototype

TODO maybe image

[5] https://github.com/vorpal-research/kex/releases/tag/sbft2023

Kex-concolic[7]

- traditional concolic engine for automatic test generation
- uses Kfg instrumentation to collect symbolic state during concrete execution
- uses Easy-Random[6] library for initial seed generation
- uses context-guided search for path exploration

TODO maybe image

[6] https://github.com/j-easy/easy-random
[7] https://github.com/vorpal-research/kex/releases/tag/sbft2023

Results

	Kex-symbolic		Kex-concolic	
Metric	**30 s**	**120 s**	**30 s**	**120 s**
Line coverage, %	53.2	59.5	57.0	65.3
Branch coverage, %	38.9	47.5	35.0	50.0
Mutation coverage, %	0.0		0.0	
Test case understandability	3.95		3.69	
Overall ranking	4.89		3.69	

Conclusions

- Kex significantly improved coverage metrics compared to previous years
  - performed on par with the other SE-based tools
- Kex has several implementation issues that affect its reliability
  - e.g. Kex failed on `ta4j` project because of bug in Kfg
- Kex needs to improve the quality of generated tests
  - generate test oracles
  - improve understandability

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repository:

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