The
University
Of
Sheffield.

Continuous Test Generation on Guava

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University of Luxembourg

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University of Porto
Portugal

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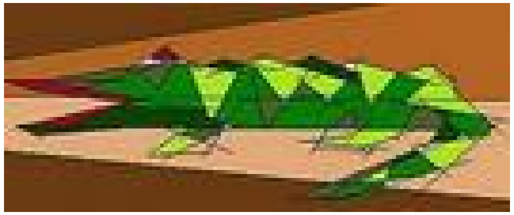
7th Symposium on Search-Based Software Engineering (SSBSE)
Bergamo, Italy

http://www.pexforfun.com/

http://mernst.github.io/randoop/

GRT

Test Apps Better



https://code.google.com/p/t2framework/

AgitarOne

http://www.agitar.com/

JTExpert

https://sites.google.com/site/saktiabdel/JTExpert

EVOSUITE

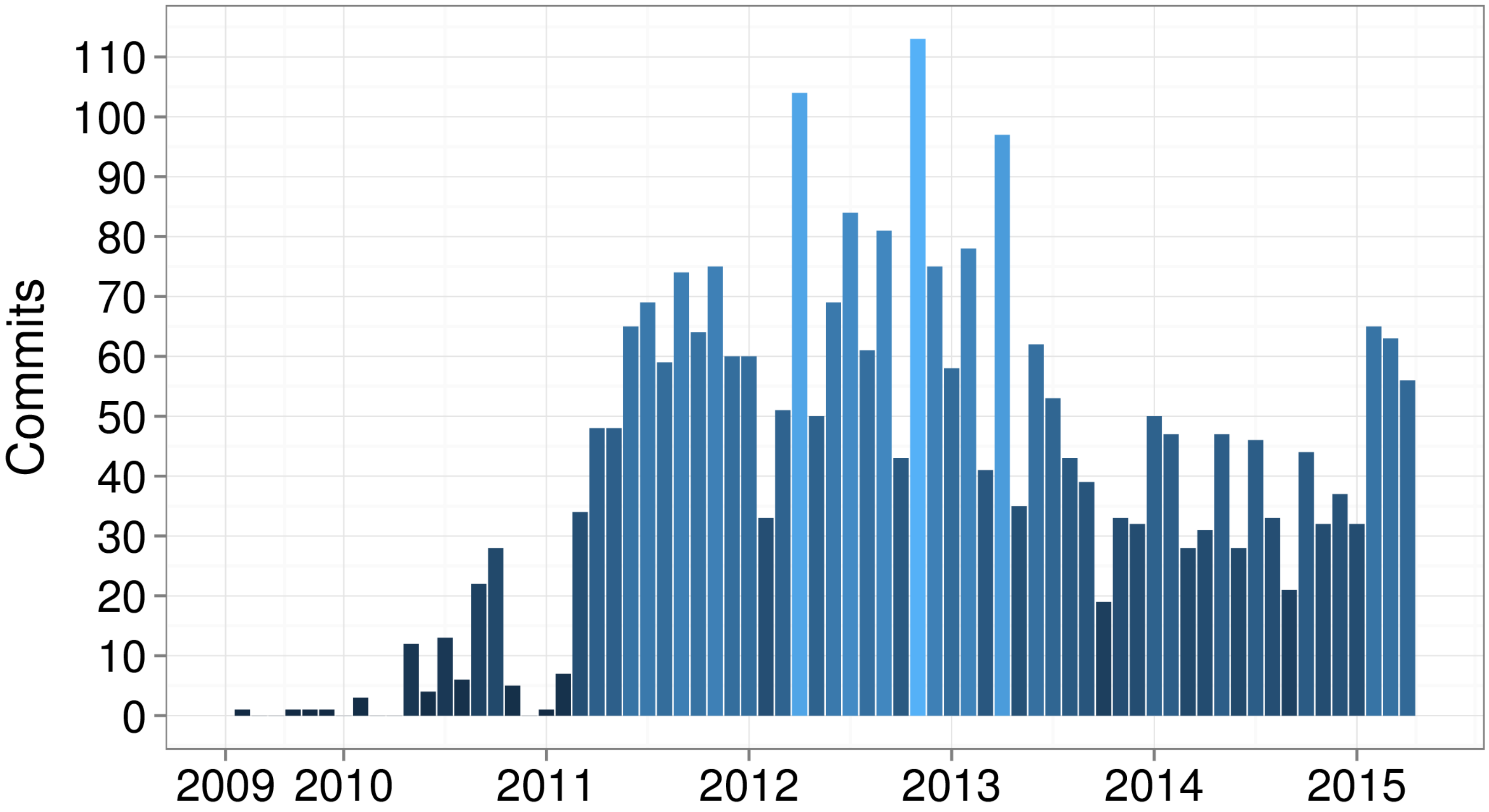
http://www.evosuite.org/

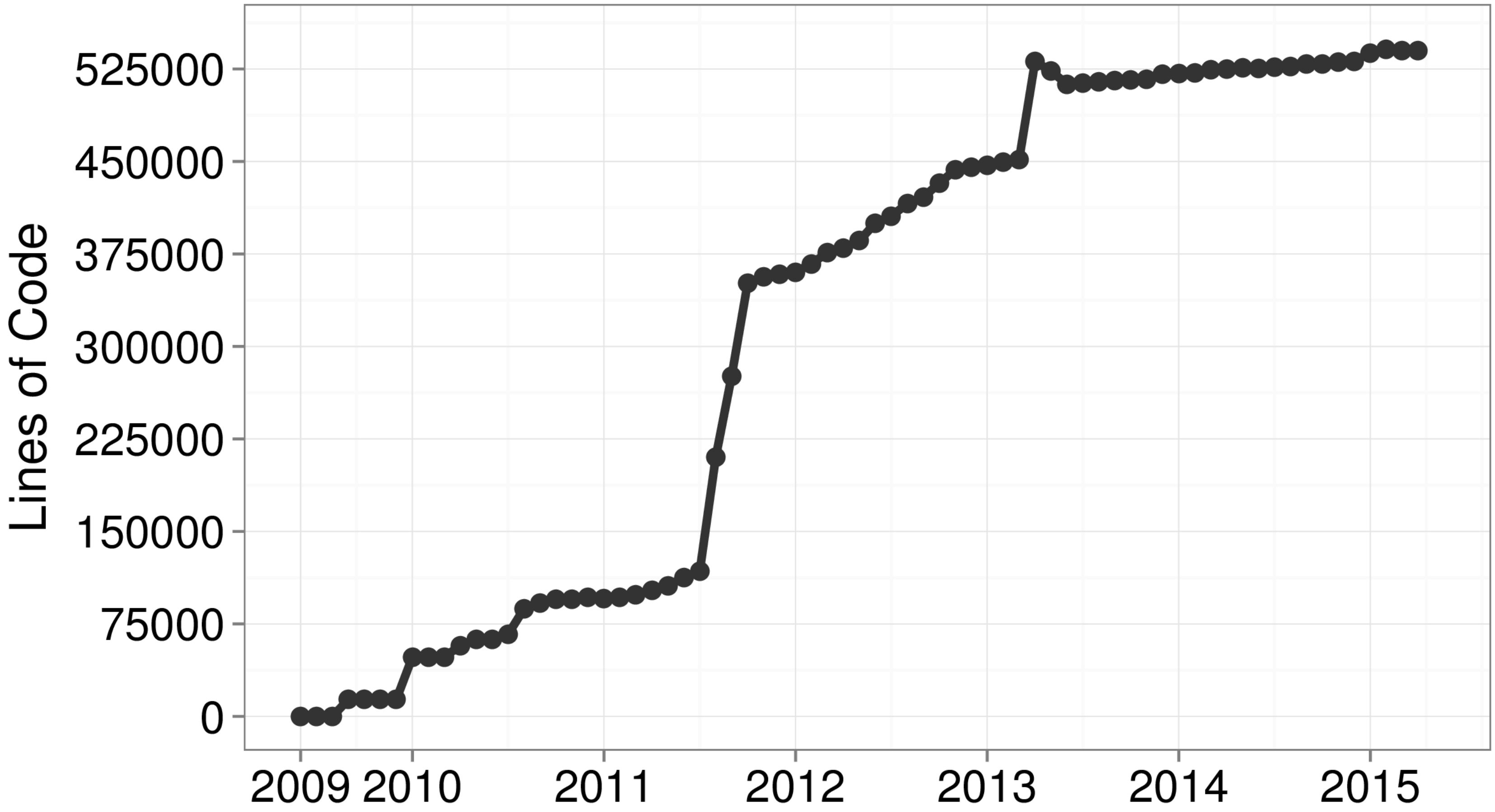
how to best use an automated unit test generation tool to maximize code coverage ?

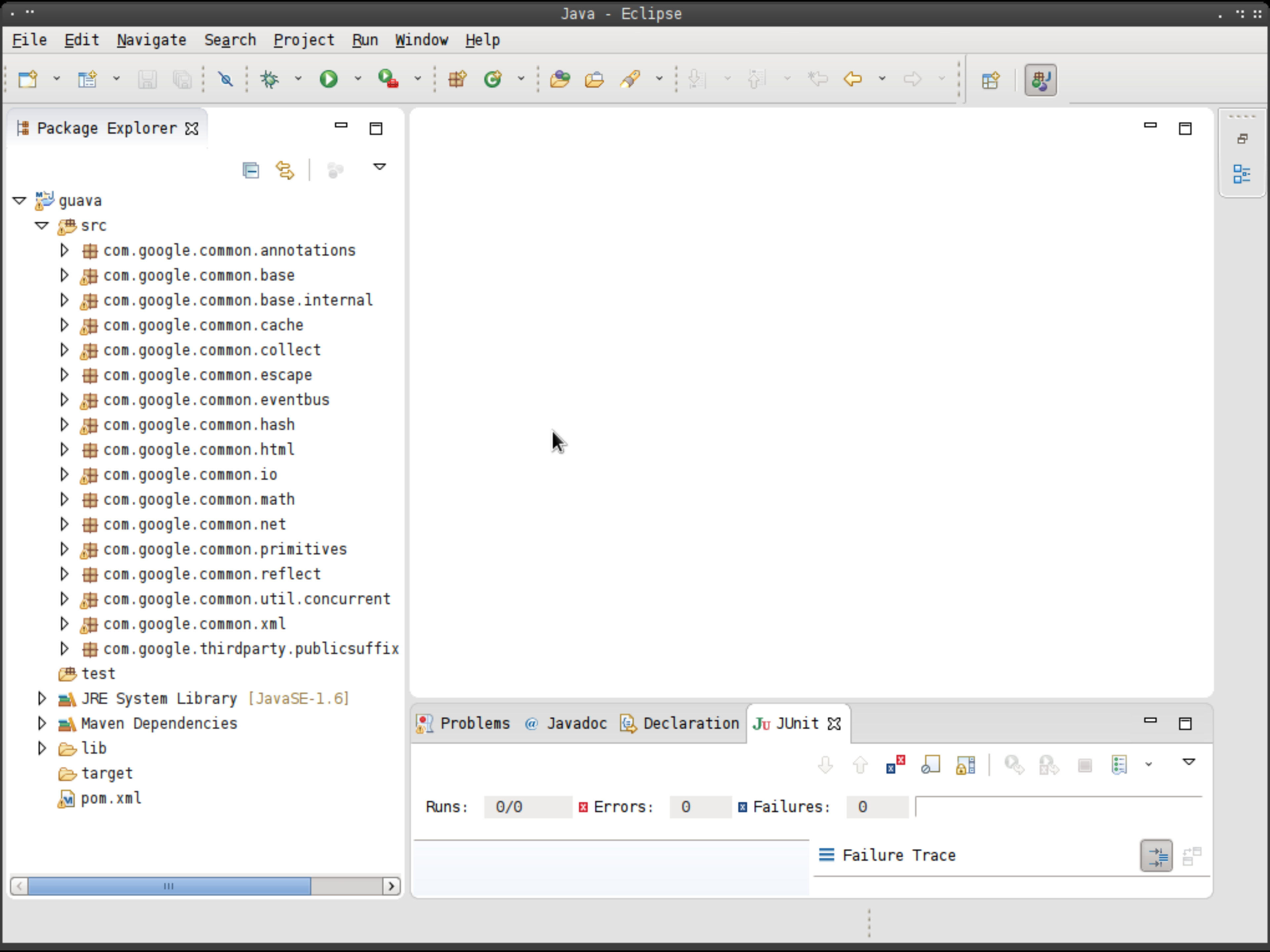
“Google Guava is an open-source set of common libraries for Java, mainly developed by Google engineers.” by wikipedia

⑂ 1,017

★ 4,651

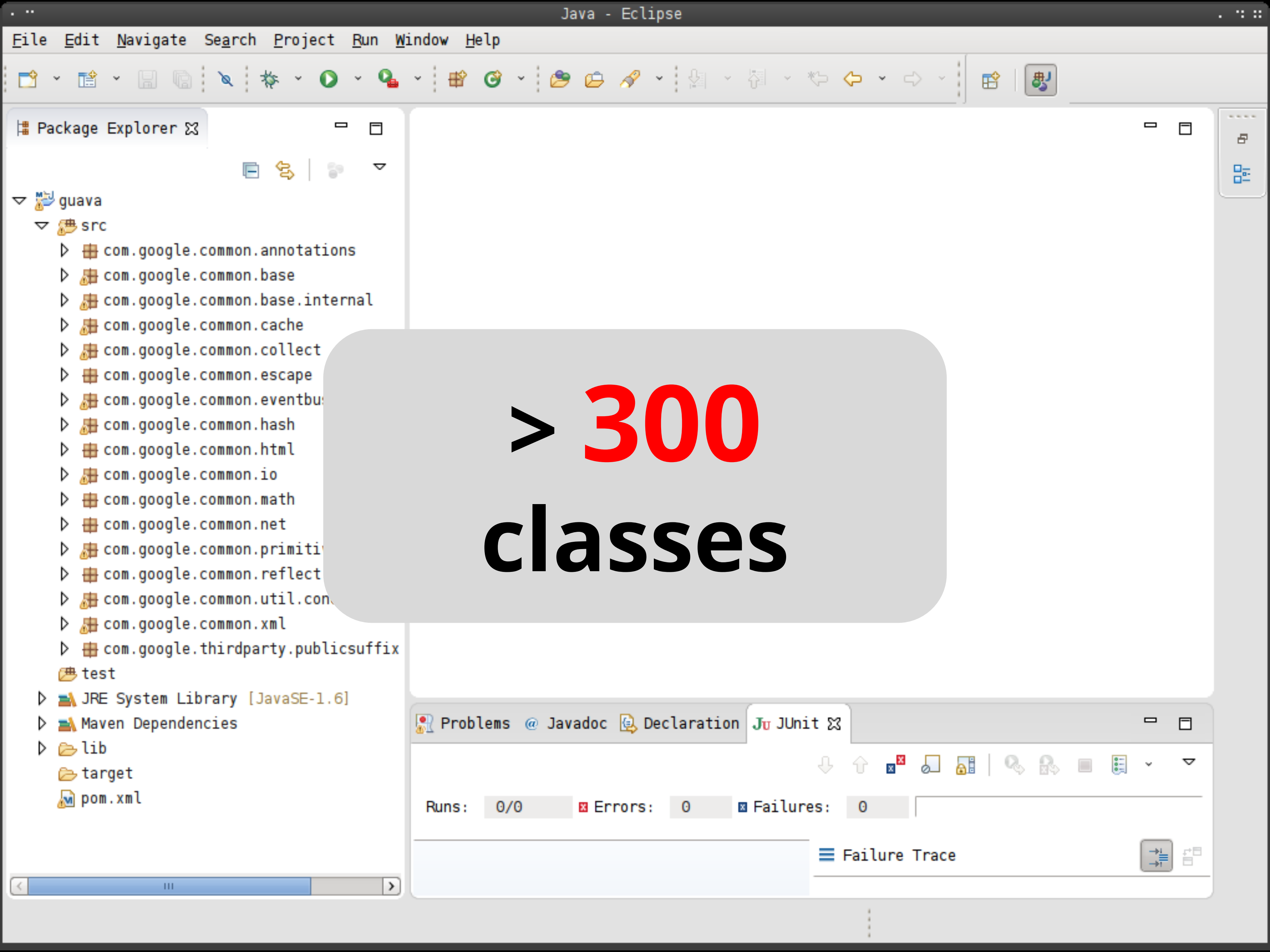

Commits
110
100
90
80
70
60
50
40
30
20
10
0
2009
2010
2011
2012
2013
2014
2015


Lines of Code
525000
450000
375000
300000
225000
150000
75000
0
2009
2010
2011
2012
2013
2014
2015



```
guava
  src
    com.google.common.annotations
    com.google.common.base
    com.google.common.base.internal
    com.google.common.cache
    com.google.common.collect
    com.google.common.escape
    com.google.common.eventbus
    com.google.common.hash
    com.google.common.html
    com.google.common.io
    com.google.common.math
    com.google.common.net
    com.google.common.primitives
    com.google.common.reflect
    com.google.common.util.concurrent
    com.google.common.xml
    com.google.thirdparty.publicsuffix
  test
  JRE System Library [JavaSE-1.6]
  Maven Dependencies
  lib
  target
  pom.xml
```

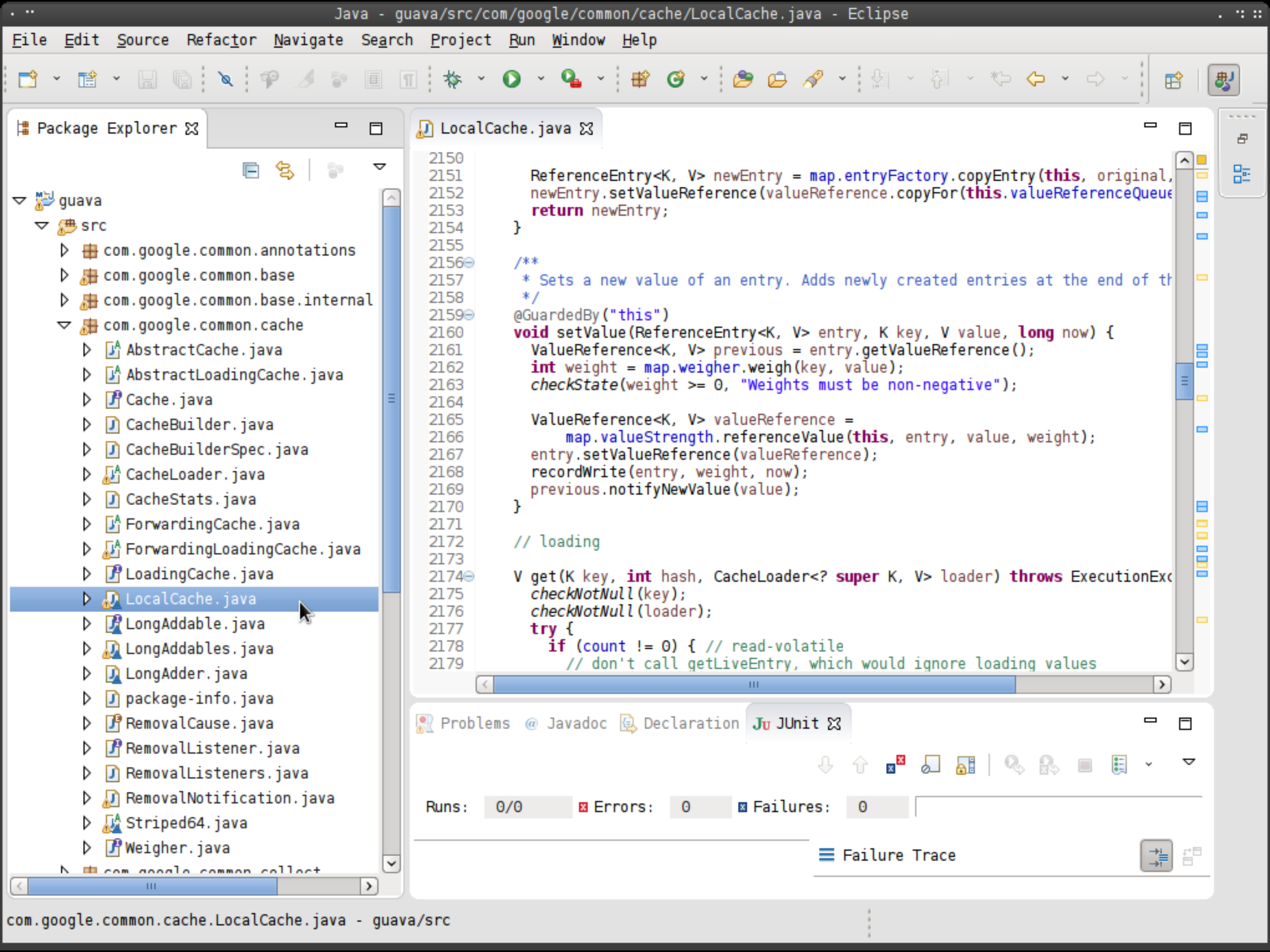
Runs: 0/0 ☒ Errors: 0 ☒ Failures: 0



```
guava
  src
    com.google.common.annotations
    com.google.common.base
    com.google.common.base.internal
    com.google.common.cache
    com.google.common.collect
    com.google.common.escape
    com.google.common.eventbu
    com.google.common.hash
    com.google.common.html
    com.google.common.io
    com.google.common.math
    com.google.common.net
    com.google.common.primiti
    com.google.common.reflect
    com.google.common.util.con
    com.google.common.xml
    com.google.thirdparty.publicsuffix
  test
  JRE System Library [JavaSE-1.6]
  Maven Dependencies
  lib
  target
  pom.xml
```

```
Runs: 0/0    Errors: 0    Failures: 0
```

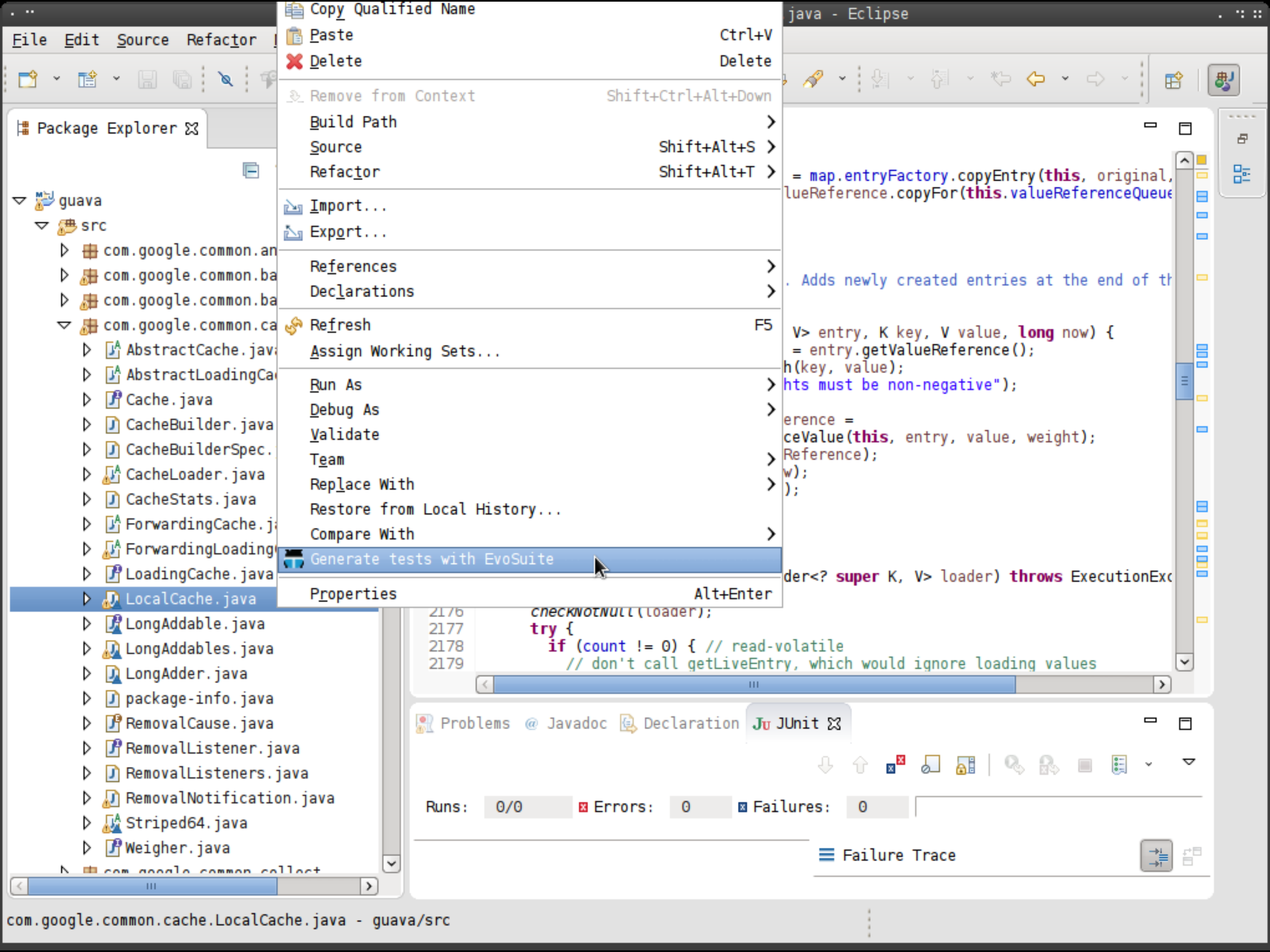
> 300 classes



```
      ReferenceEntry<K, V> newEntry = map.entryFactory.copyEntry(this, original,
      newEntry.setValueReference(valueReference.copyFor(this.valueReferenceQueue
      return newEntry;
    }

    /**
     * Sets a new value of an entry. Adds newly created entries at the end of th
     */
    @GuardedBy("this")
    void setValue(ReferenceEntry<K, V> entry, K key, V value, long now) {
      ValueReference<K, V> previous = entry.getValueReference();
      int weight = map.weigher.weigh(key, value);
      checkState(weight >= 0, "Weights must be non-negative");

      ValueReference<K, V> valueReference =
          map.valueStrength.referenceValue(this, entry, value, weight);
      entry.setValueReference(valueReference);
      recordWrite(entry, weight, now);
      previous.notifyNewValue(value);
    }

    // loading

    V get(K key, int hash, CacheLoader<? super K, V> loader) throws ExecutionExc
      checkNotNull(key);
      checkNotNull(loader);
      try {
        if (count != 0) { // read-volatile
          // don't call getLiveEntry, which would ignore loading values
```

Runs: 0/0 ☒ Errors: 0 ☒ Failures: 0

com.google.common.cache.LocalCache.java - guava/src



```
= map.entryFactory.copyEntry(this, original,
lueReference.copyFor(this.valueReferenceQueue

. Adds newly created entries at the end of th

V> entry, K key, V value, long now) {
= entry.getValueReference();
h(key, value);
hts must be non-negative");

erence =
ceValue(this, entry, value, weight);
Reference);
w);
);

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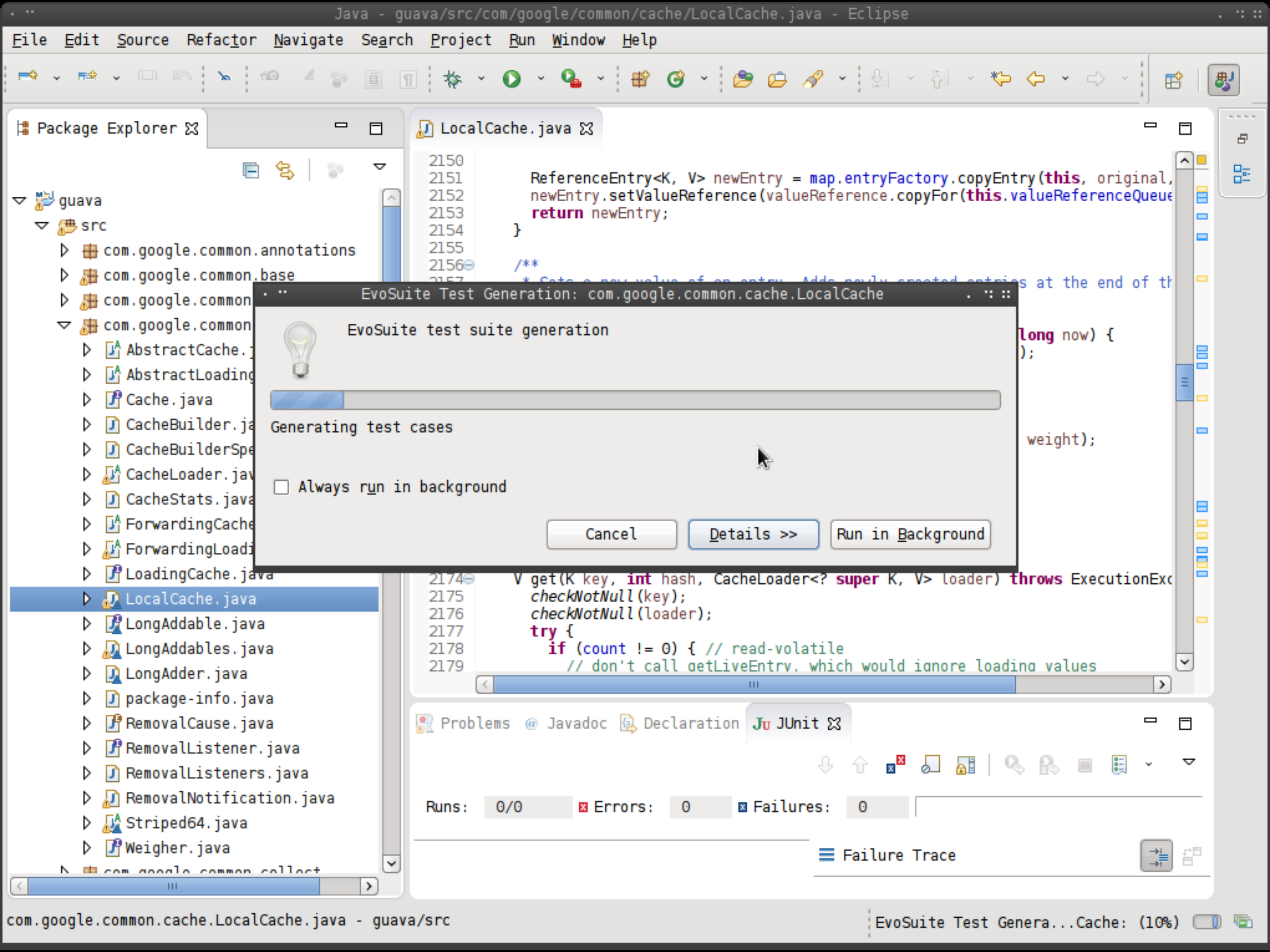

```
        ReferenceEntry<K, V> newEntry = map.entryFactory.copyEntry(this, original,
        newEntry.setValueReference(valueReference.copyFor(this.valueReferenceQueue
        return newEntry;
      }

      /**
       * Sets a new value of an entry. Adds newly created entries at the end of th
```

```
long now) {
);
weight);
```

```
      V get(K key, int hash, CacheLoader<? super K, V> loader) throws ExecutionExc
        checkNotNull(key);
        checkNotNull(loader);
        try {
          if (count != 0) { // read-volatile
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```

EvoSuite Test Generation: com.google.common.cache.LocalCache

EvoSuite test suite generation

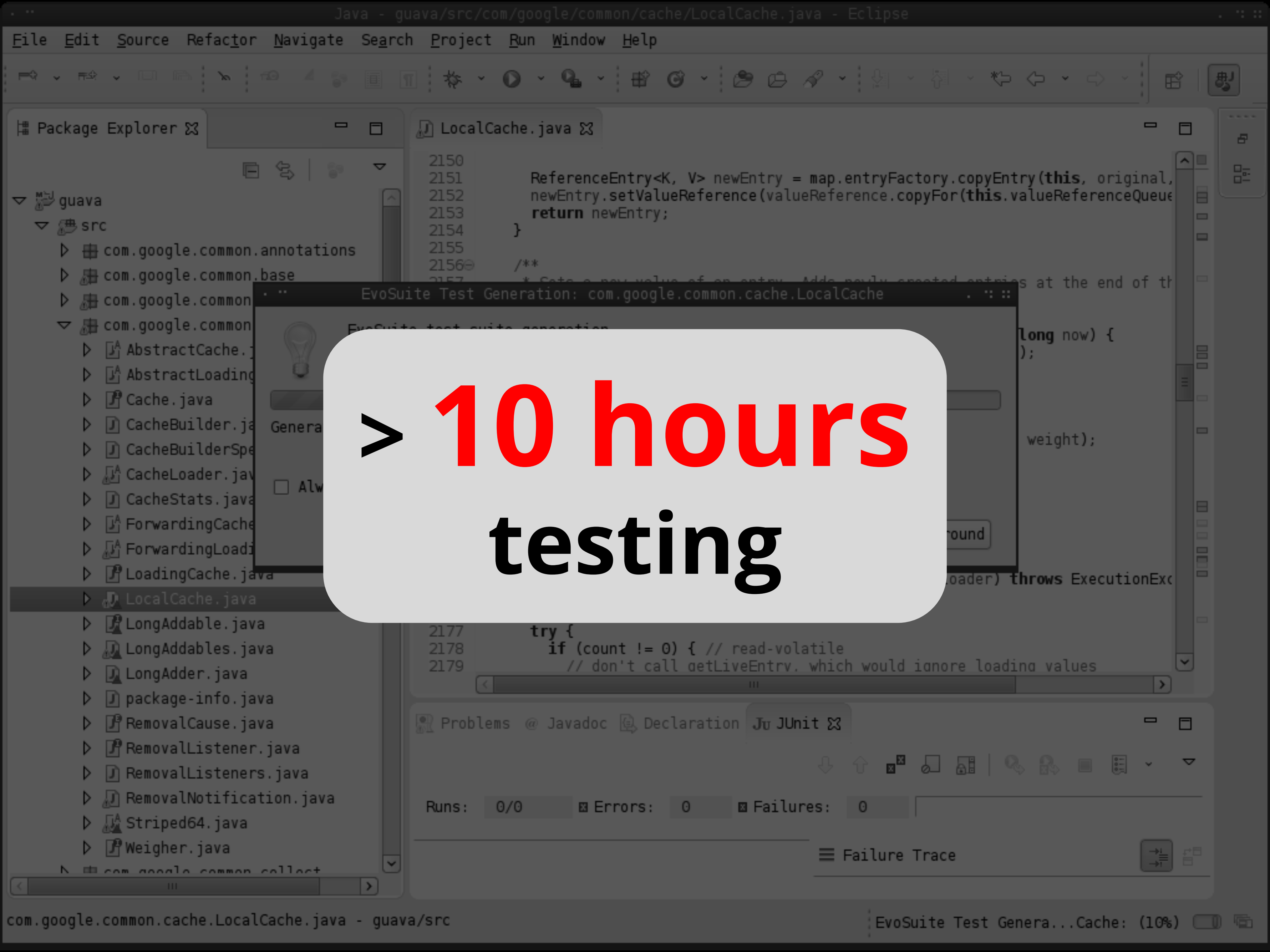
Generating test cases

☐ Always run in background

Runs: 0/0 Errors: 0 Failures: 0

com.google.common.cache.LocalCache.java - guava/src

EvoSuite Test Genera...Cache: (10%)



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EvoSuite Test Generation: com.google.common.cache.LocalCache

EvoSuite test suite generation

Genera

□ Alw

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        try {
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```

Runs: 0/0 ☒ Errors: 0 ☒ Failures: 0

com.google.common.cache.LocalCache.java - guava/src

EvoSuite Test Genera...Cache: (10%)

> **10 hours**

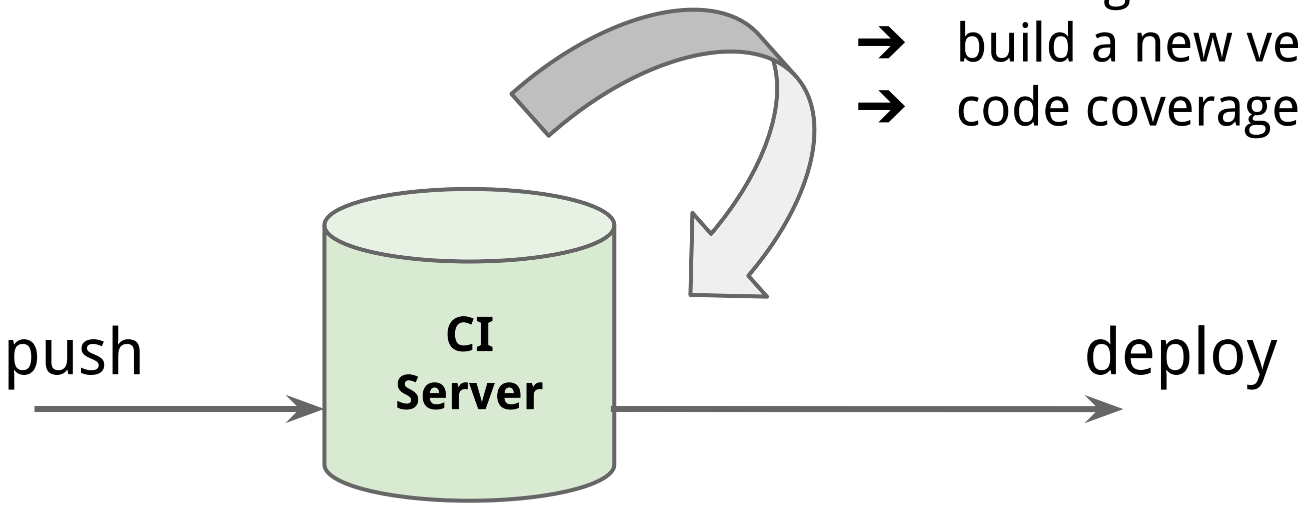
testing

Continuous Test Generation

on Guava

Continuous Integration

➔ run regression test suite
➔ build a new version
➔ code coverage reports

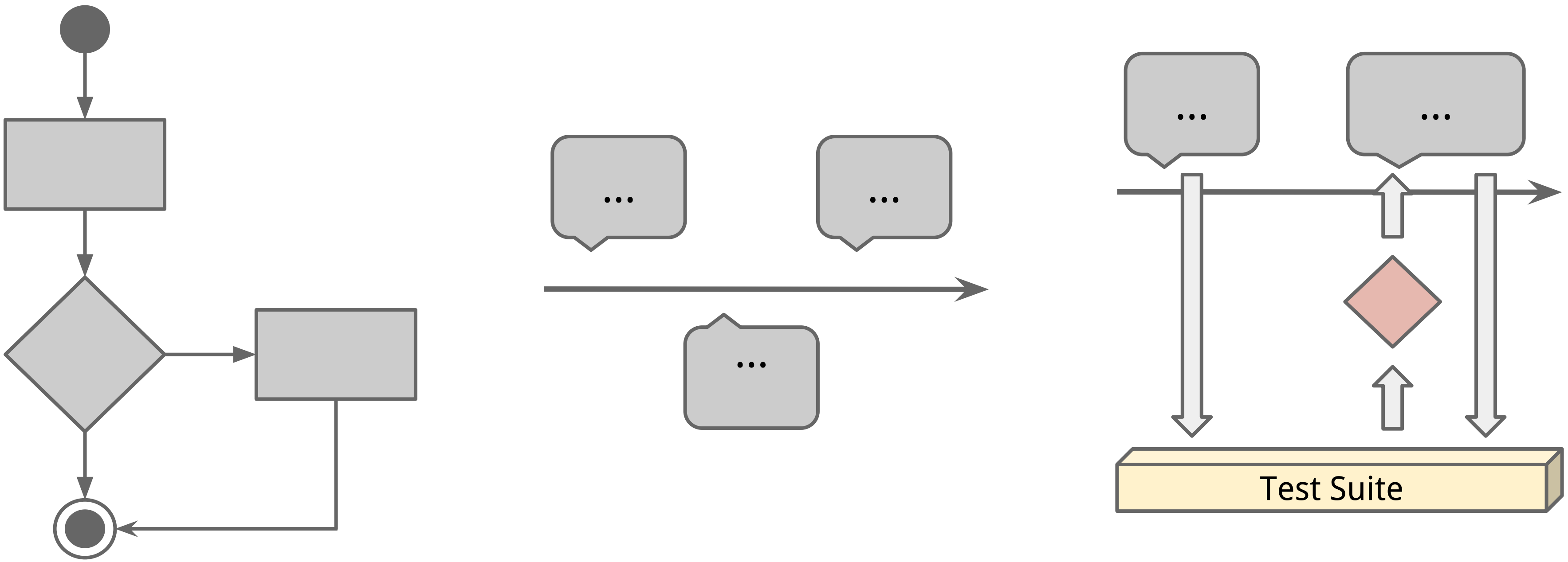


Jenkins

Hudson

CruiseControl

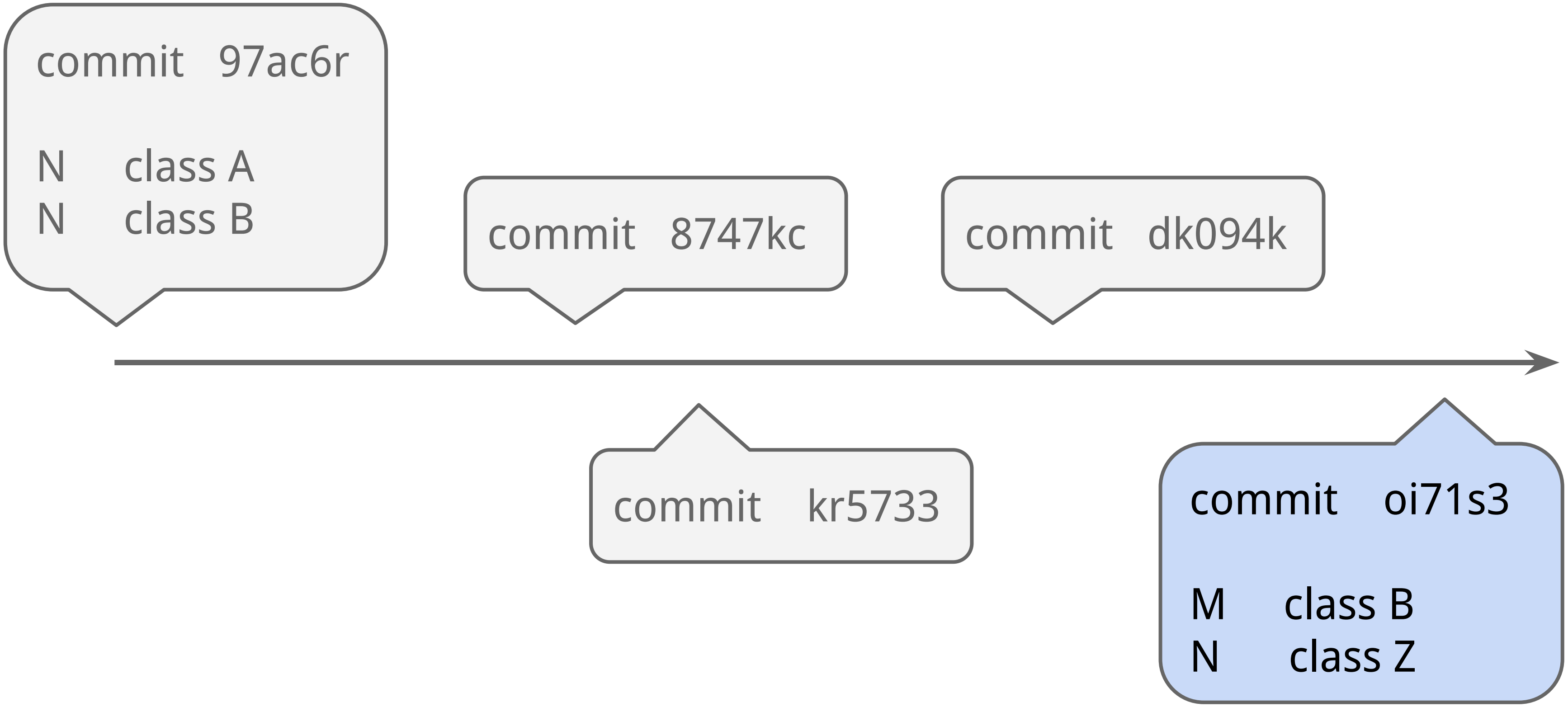
Continuous Test Generation (CTG)



Time Budget Allocation based on Complexity

	# Branches	time
Class A	10	2.7 min
Class B	5	1.3 min

Repository History



commit 97ac6r

N class A
N class B

commit 8747kc

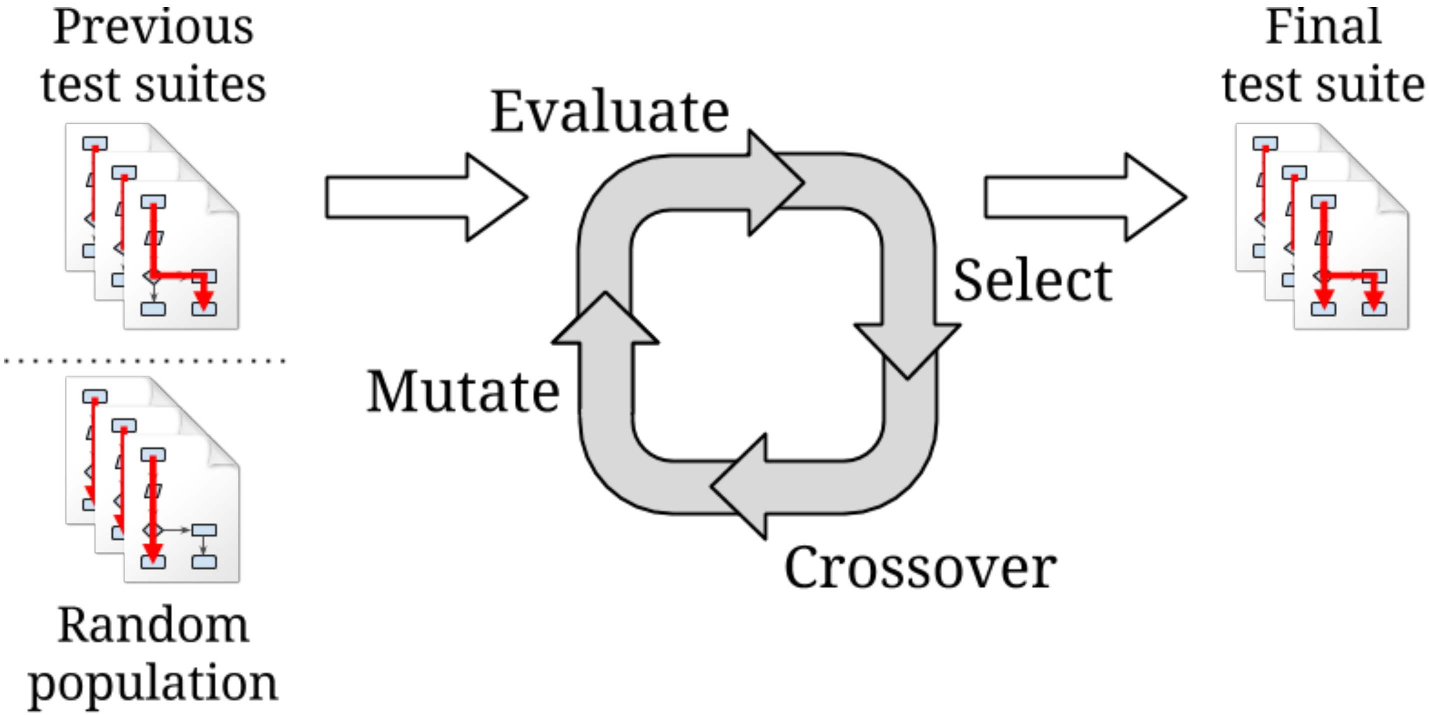
commit dk094k

commit kr5733

commit oi71s3

M class B
N class Z

Seeding previous test suite generated



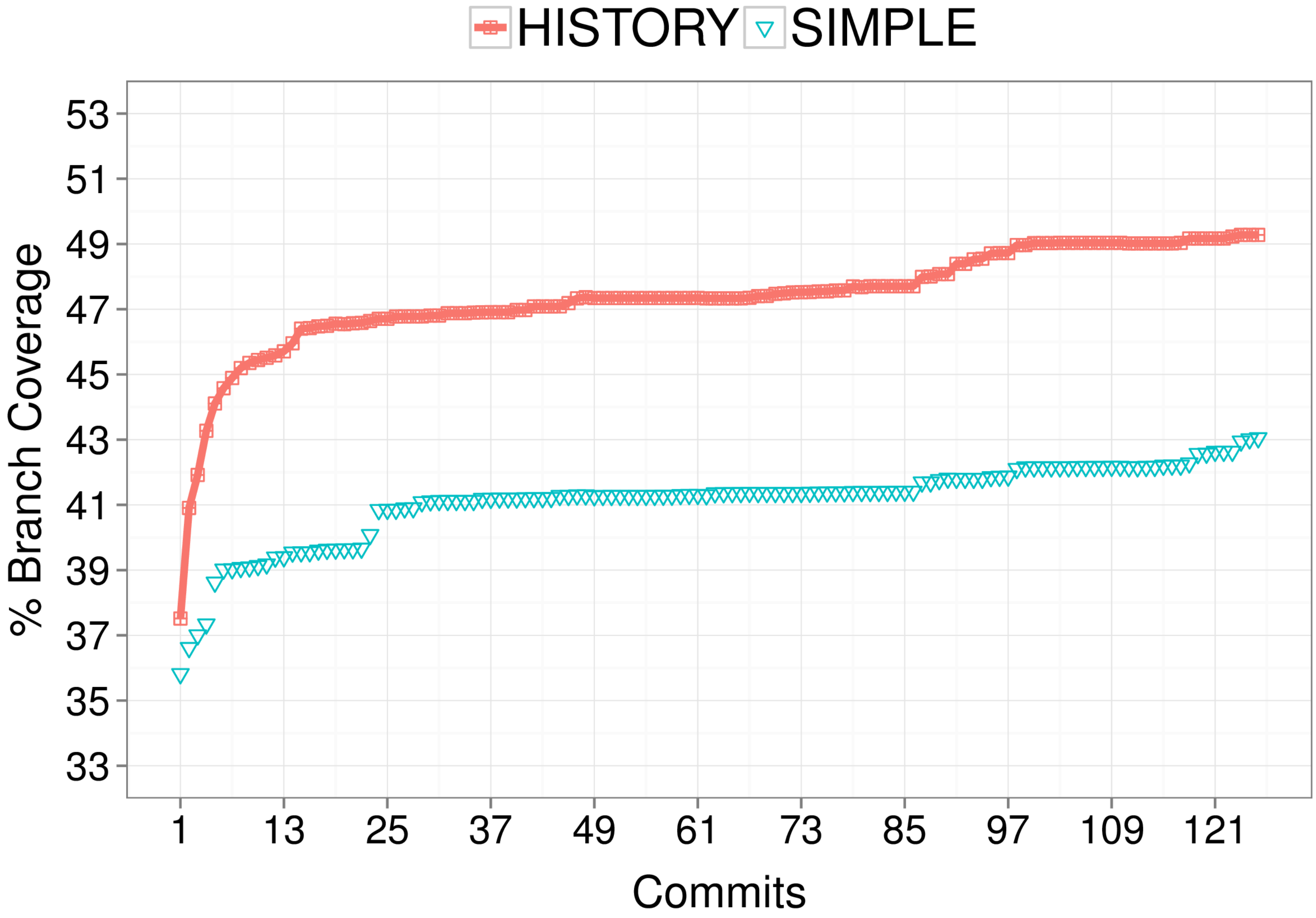
Evaluation

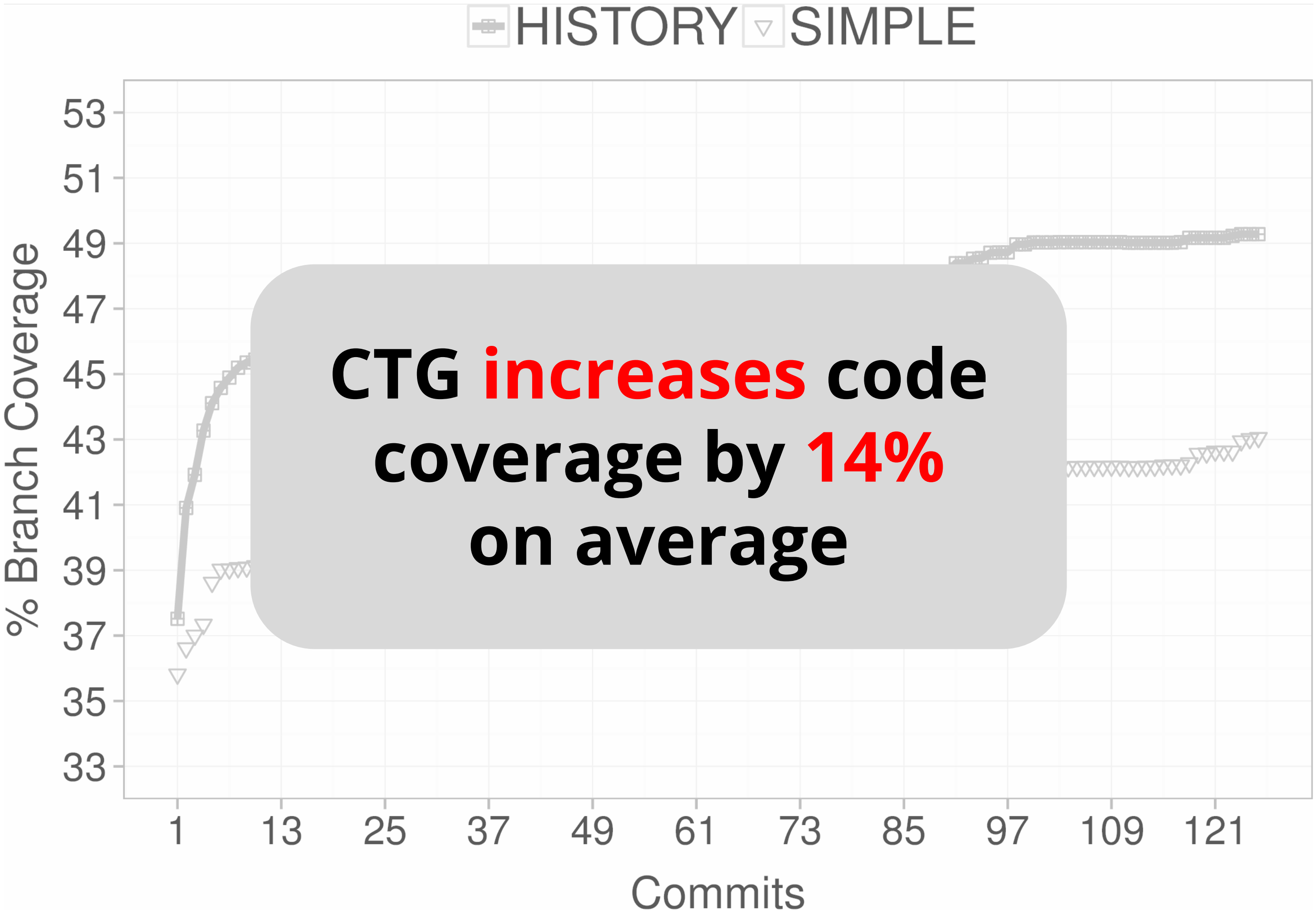
126 commits

all commits between v17 and v18

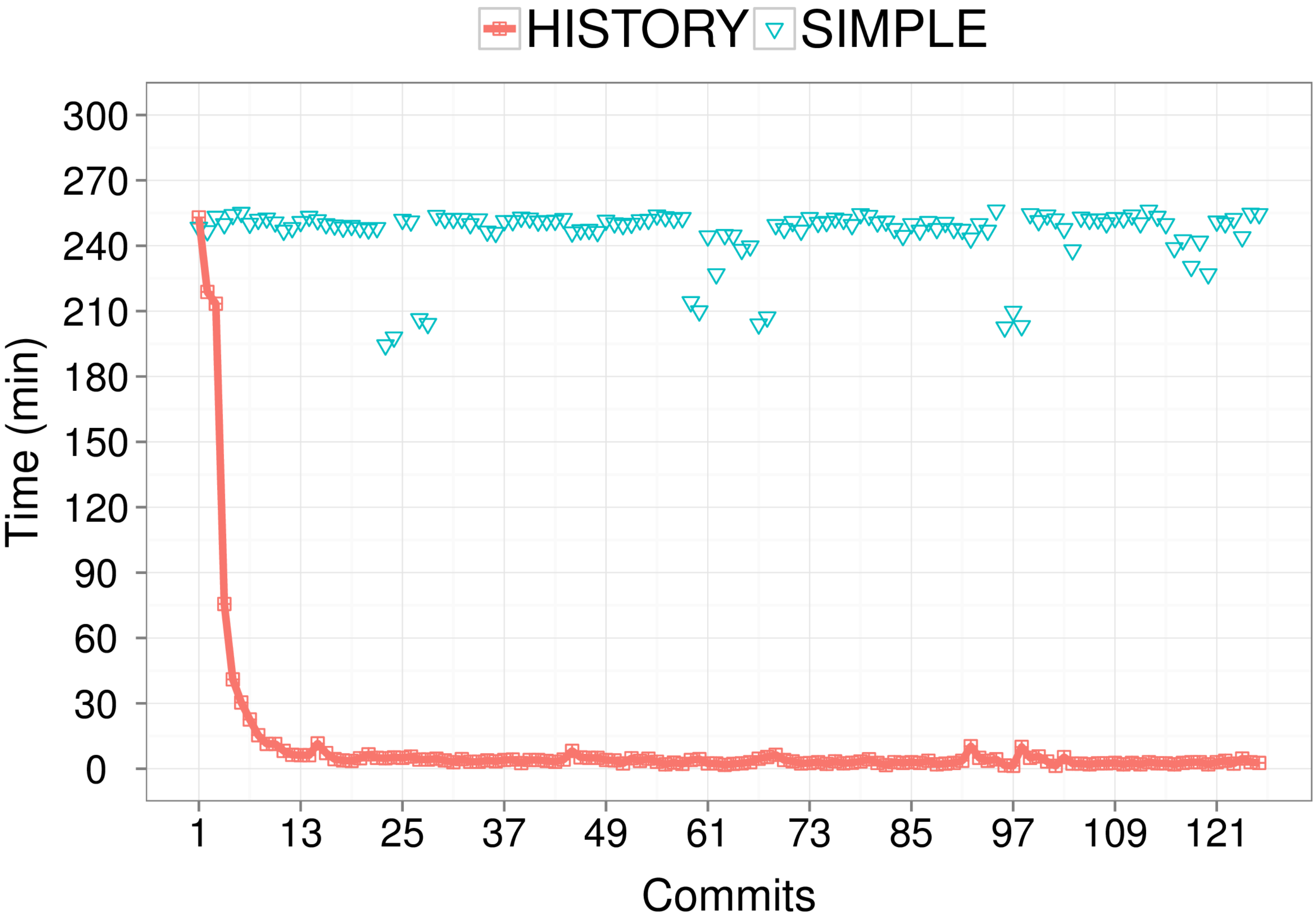
1 minute per class under test

http://viocorp.com/wp-content/uploads/2014/11/trustTheNumbers_stopwatch.png


HISTORY
SIMPLE
% Branch Coverage
53
51
49
47
45
43
41
39
37
35
33
1
13
25
37
49
61
73
85
97
109
121
Commits



CTG **increases** code coverage by **14%** on average


HISTORY
SIMPLE
Time (min)
300
270
240
210
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1
13
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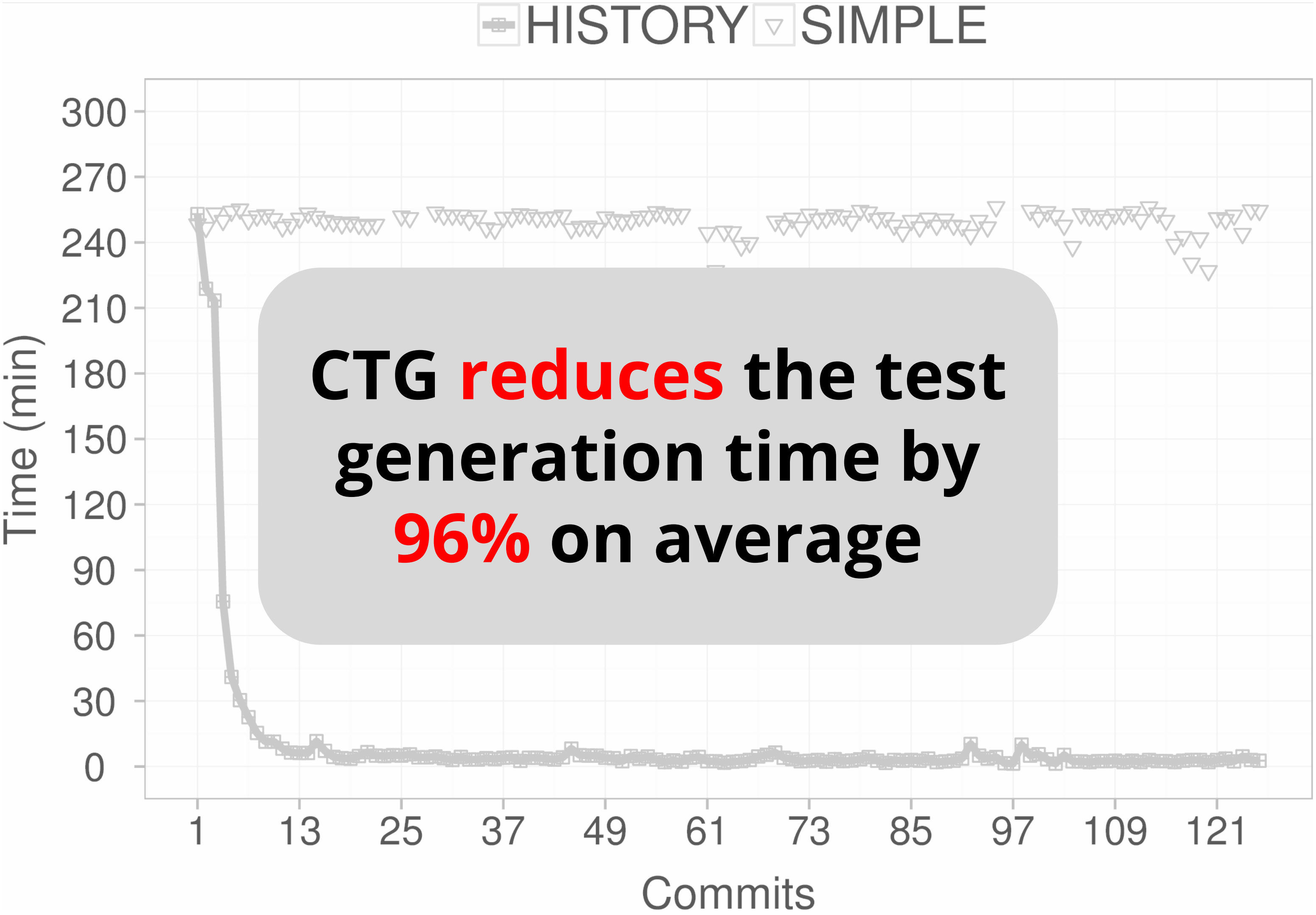
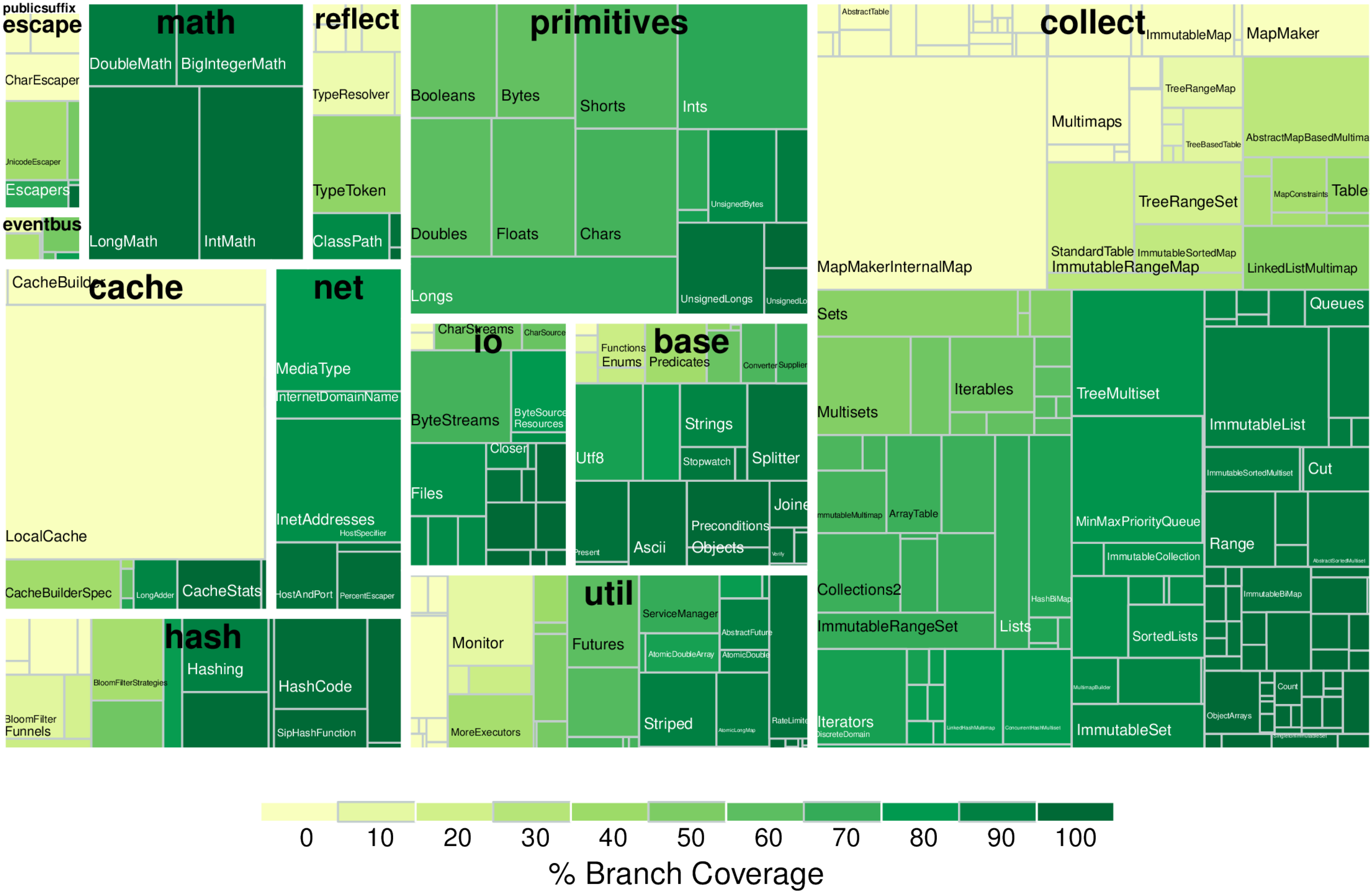
37
49
61
73
85
97
109
121
Commits



CTG **reduces** the test generation time by **96%** on average



publicsuffix
escape
CharEscaper
UnicodeEscaper
Escapers
eventbus
math
DoubleMath
BigIntegerMath
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TypeResolver
TypeToken
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ImmutableSet
SingletonImmutableSet
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LocalCache
CacheBuilderSpec
LongAdder
CacheStats
net
MediaType
InternetDomainName
InetAddresses
HostSpecifier
HostAndPort
PercentEscaper
io
CharStreams
CharSource
ByteStreams
ByteSource
Resources
Closer
Files
base
Functions
Enums
Predicates
Converter
Supplier
Utf8
Strings
Stopwatch
Splitter
Joiner
Present
Ascii
Preconditions
Objects
Verify
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BloomFilterStrategies
Hashing
HashCode
SipHashFunction
BloomFilter
Funnels
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Monitor
Futures
ServiceManager
AbstractFuture
AtomicDoubleArray
AtomicDouble
MoreExecutors
Striped
AtomicLongMap
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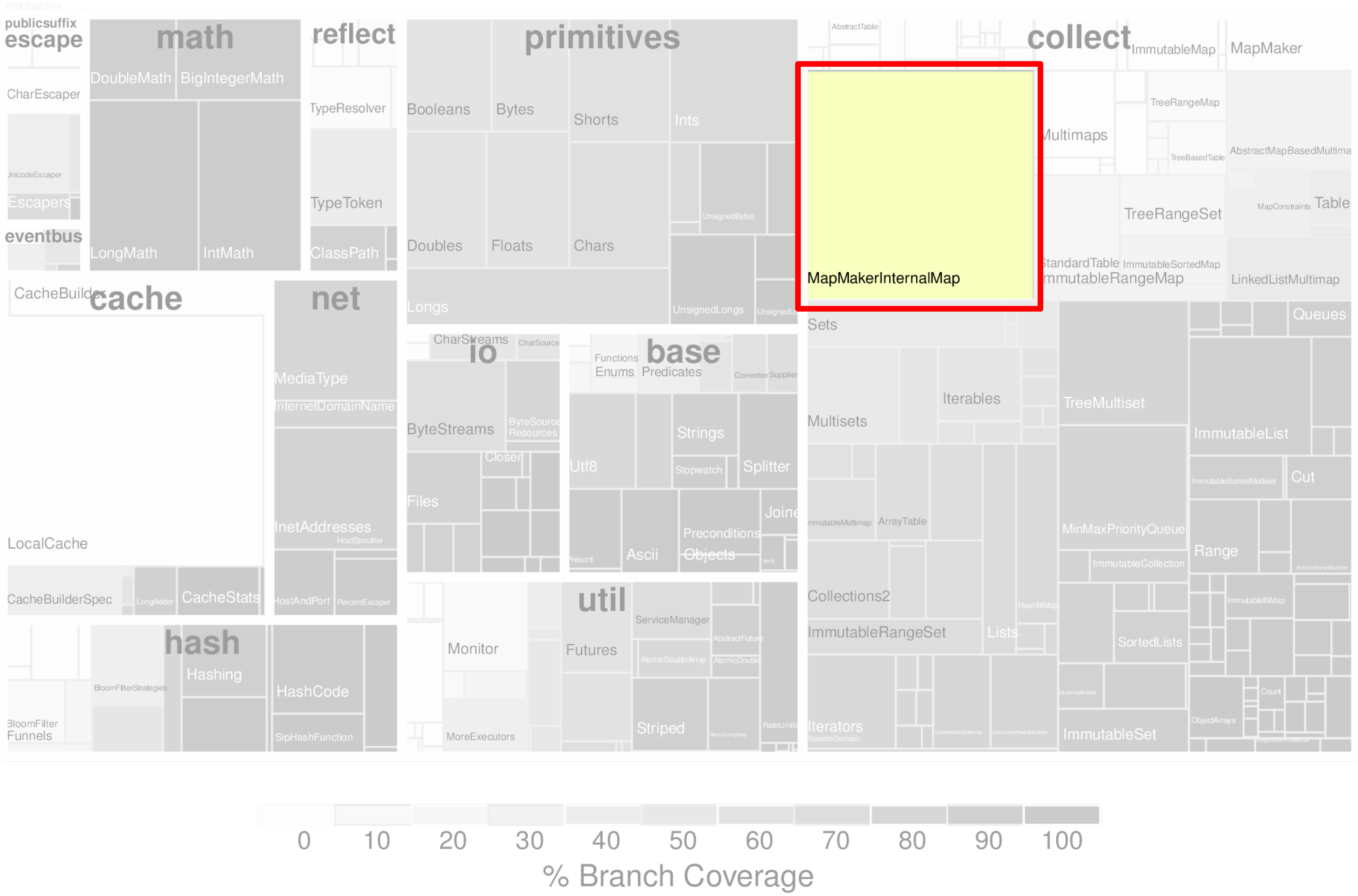
% Branch Coverage


publicsuffix
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CacheBuilder
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LocalCache
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LongAdder
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AtomicDouble
Striped
AtomicLongMap
RateLimiter
MoreExecutors
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80
90
100
% Branch Coverage

```java
/**
 * Creates a new, empty map with the specified strategy,
 * initial capacity and concurrency level.
 */
public MapMakerInternalMap(MapMaker builder) {
  concurrencyLevel = Math.min(builder.getConcurrencyLevel(), MAX_SEGMENTS);

  keyStrength = builder.getKeyStrength();
  valueStrength = builder.getValueStrength();

  keyEquivalence = builder.getKeyEquivalence();
  valueEquivalence = valueStrength.defaultEquivalence();

  maximumSize = builder.maximumSize;
  expireAfterAccessNanos = builder.getExpireAfterAccessNanos();
  expireAfterWriteNanos = builder.getExpireAfterWriteNanos();

  entryFactory = EntryFactory.getFactory(keyStrength,
                                         expires(), evictsBySize());
  ticker = builder.getTicker();

  removalListener = builder.getRemovalListener();
  removalNotificationQueue = (removalListener == NullListener.INSTANCE)
      ? MapMakerInternalMap.<RemovalNotification<K, V>>discardingQueue()
      : new ConcurrentLinkedQueue<RemovalNotification<K, V>>();

  ... // +26 lines of code
}
```

```
/**
 * Creates a new, empty map with the specified strategy,
 * initial capacity and concurrency level.
 */
public MapMakerInternalMap(MapMaker builder) {
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  keyEquivalence = builder.getKeyEquivalence();
  valueEquivalence = valueStrength.defaultEquivalence();

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public MapMakerInternalMap(MapMaker builder)  {
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   ...
}
```
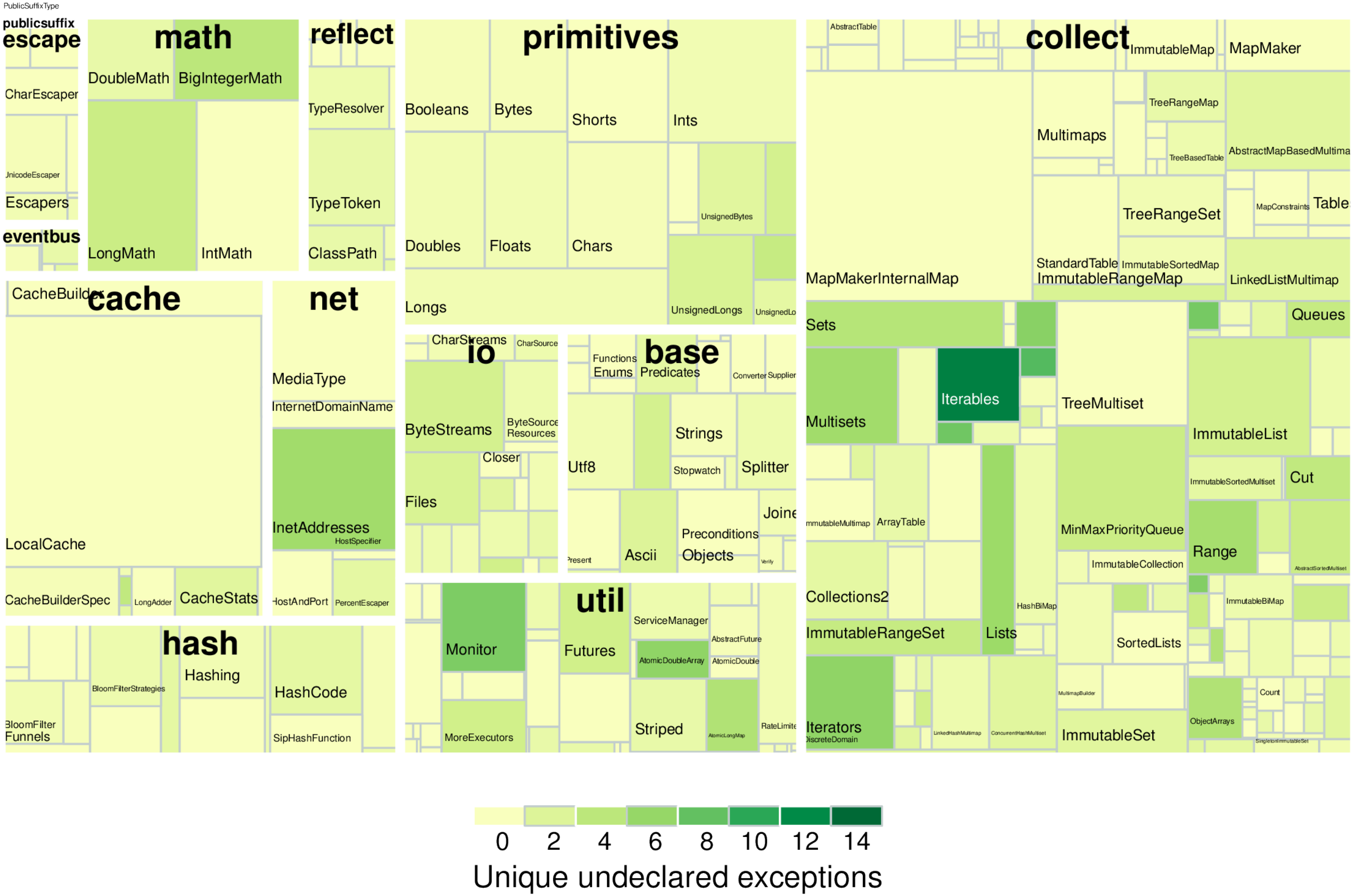

- ➔ **2692** lines of code

- ➔ 2 interfaces
- ➔ 42 static classes (e.g., class Segment<K, V> has **762** lines of code)
- ➔ 2 inner classes
- ➔ 3 abstract classes
- ➔ 3 enum classes


PublicSuffixType
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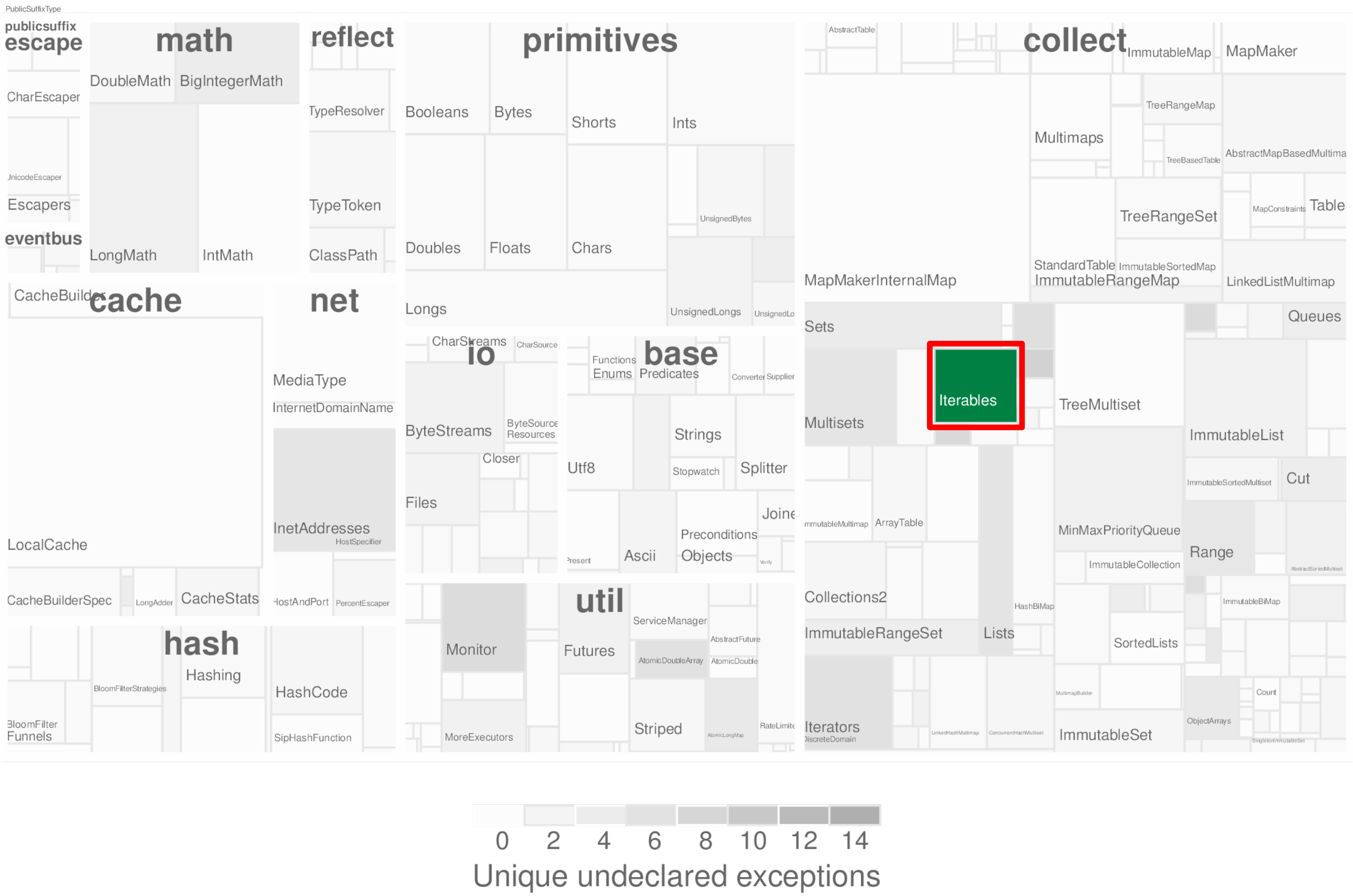
Unique undeclared exceptions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InetAddresses
HostSpecifier
HostAndPort
PercentEscaper
CharStreams
io
CharSource
ByteStreams
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Predicates
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Utf8
Strings
Stopwatch
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AtomicLongMap
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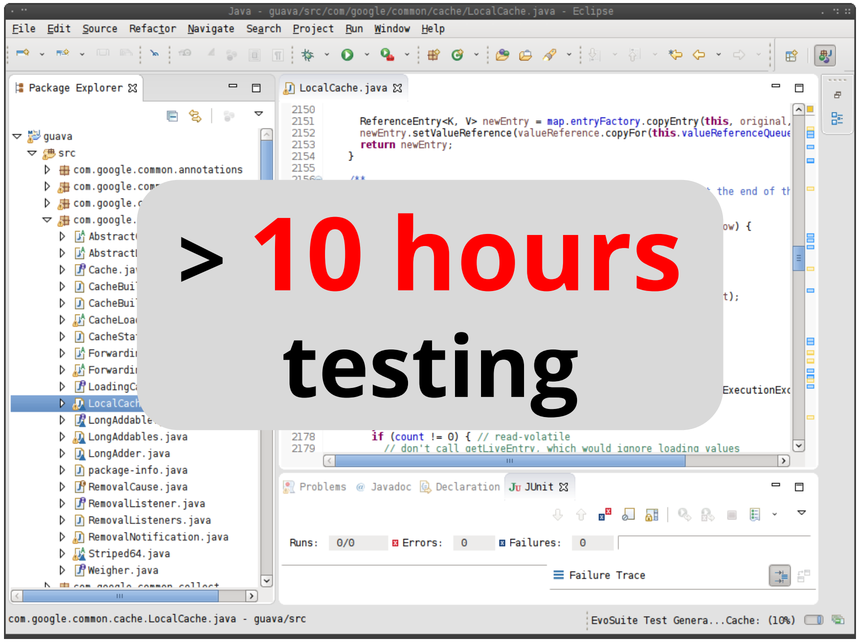
Unique undeclared exceptions

```
/**
 * Removes, from an iterable, every element that satisfies
 * the provided predicate.
 *
 * @param removeFrom the iterable to (potentially) remove
 * elements from
 * @param predicate a predicate that determines whether an
 * element should be removed
 * @return {@code true} if any elements were removed from
 * the iterable
 *
 * @throws UnsupportedOperationException if the iterable does
 * not support {@code remove()}
 */
public static <T> boolean removeIf(
    Iterable<T> removeFrom,
    Predicate<? super T> predicate) {

  if (removeFrom instanceof RandomAccess &&
       removeFrom instanceof List) {
    return removeIfFromRandomAccessList(
        (List<T>) removeFrom, checkNotNull(predicate));
  }

  return Iterators.removeIf(removeFrom.iterator(), predicate);
}
```

```java
/**
 * Removes, from an iterable, every element that satisfies
 * the provided predicate.
 *
 * @param removeFrom the iterable to (potentially) remove
 * elements from
 * @param predicate a predicate that determines whether an
 * element should be removed
 * @return {@code true} if any elements were removed from
 * the iterable
 *
 * @throws UnsupportedOperationException if the iterable does
 * not support {@code remove()}
 */
public static <T> boolean removeIf(
    Iterable<T> removeFrom,
    Predicate<? super T> predicate) {

  if (removeFrom instanceof RandomAccess &&
      removeFrom instanceof List) {
    return removeIfFromRandomAccessList(
        (List<T>) removeFrom, checkNotNull(predicate));
  }

  return Iterators.removeIf(removeFrom.iterator(), predicate);
}
```



```
      ReferenceEntry<K, V> newEntry = map.entryFactory.copyEntry(this, original,
      newEntry.setValueReference(valueReference.copyFor(this.valueReferenceQueue
      return newEntry;
    }

    /**
         the end of th
         ow) {
         t);
         ExecutionExc
        if (count != 0) { // read-volatile
          // don't call getLiveEntry, which would ignore loading values
```

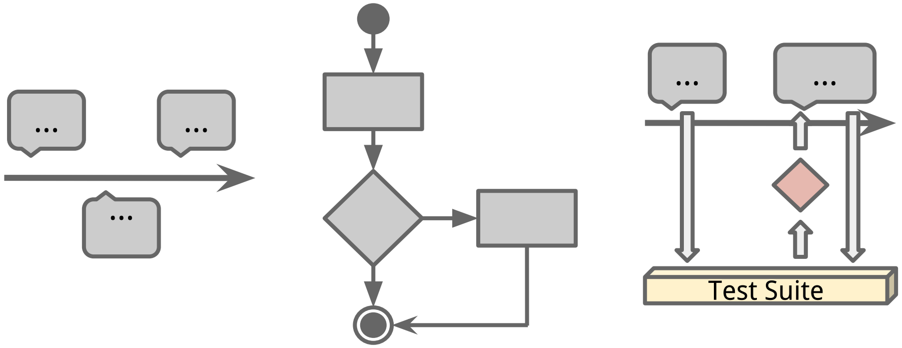
Runs: 0/0 Errors: 0 Failures: 0

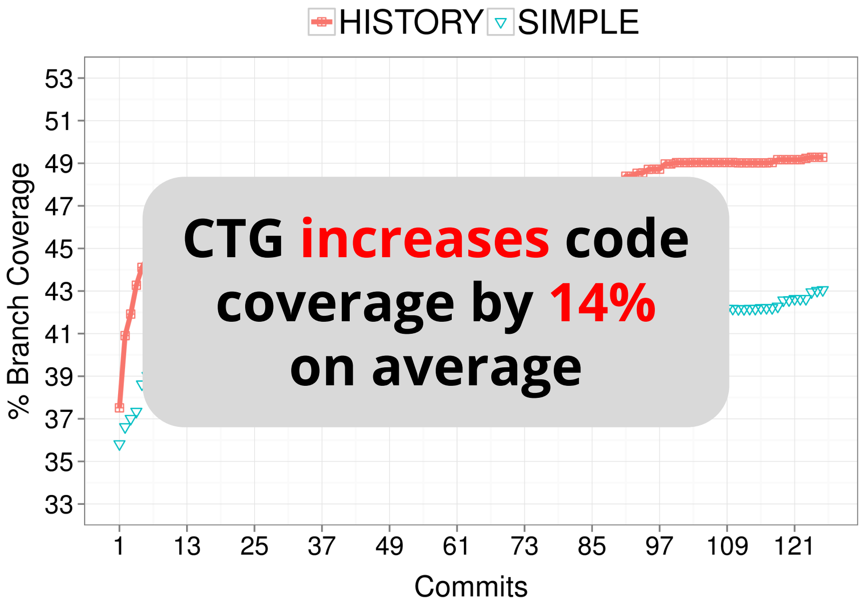
com.google.common.cache.LocalCache.java - guava/src

EvoSuite Test Genera...Cache: (10%)

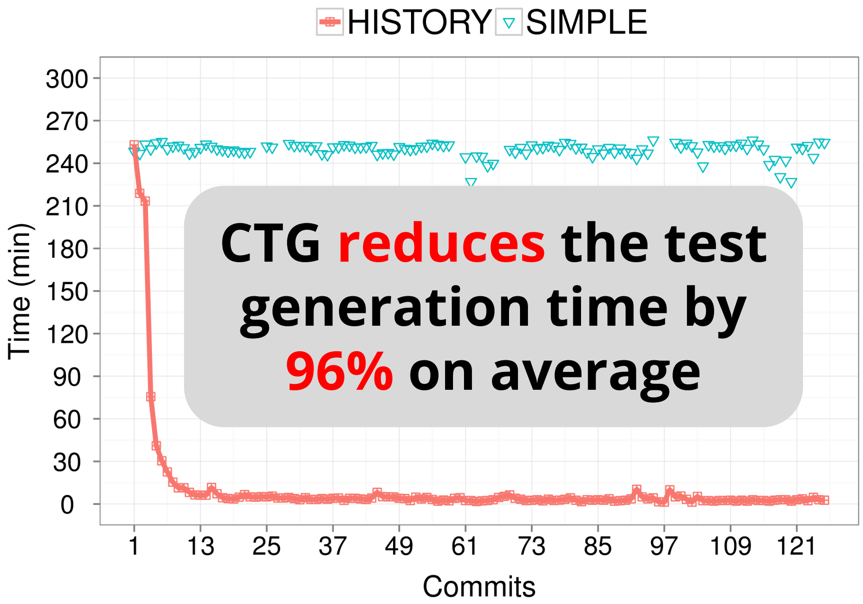
> 10 hours testing

Continuous Test Generation (CTG)





CTG increases code coverage by 14% on average



CTG reduces the test generation time by 96% on average

EVOSUITE

http://www.evosuite.org/