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**Part 1:**

**CacheEntry.access**

Inputs: *count*, *accesses, time*

Equivalence classes:

*count*: <0, 0, [1, 9], 10, >10, INT\_MAX

*accesses(time)*: 0 access, 1 accesses ~ 9 accesses, 10 accesses, > 10accesses

*time*: <0, >= 0

Test cases:

(1). count < 0, 0 access, time < 0.

(2). count = INT\_MAX, 0 access, time >= 0.

(2). count = 0, 0 access, time >= 0.

(3). count = 1, 1 access, time >= 0.

(4). count = 9, 9 accesses, time >= 0.

(5). count = 10, 10 accesses, time >= 0.

(6). count = 12, 12 accesses, time >= 0.

Failed tests:

1. Method: testNegativeCountValueNegativeTime()

Test case: (1)

Equivalence classes: count < 0, 0 access, time < 0

Robustness conditions: count < 0, time < 0

Boundary conditions: 0 access

1. Method: testMAXCountValue()

Test case: (2)

Equivalence classes: count = INT\_MAX, 0 < accesses < 10 (1 access), time >= 0

Robustness conditions: count = INT\_MAX

Boundary conditions: 1 access

Bugs:

1. Allows variable *count* to be negative, no IllegalStateException thrown.
2. Allows variable *time* to be negative, no IllegalArgumentException thrown.
3. count may overflow.

**Cache.remove**:

Input: *key*, *entries*

Equivalence classes:

*key*: null, existing key, non-existing key

*entries*: 0 entry, 1 entry, partialSize entries, fullSize -1 entries, fullSize entries.

Test cases:

(1). Key = null, 0 entry.

(2). Key = existing key, 1 entry.

(3). Key = existing key, fullSize-1 entries

(4). Key = non-existing key, fullSize entries.

(5). Key = non-existing key, 3 entries.

Failed tests:

1. Method: testWithNonExistingKeyAndEntriesNonFullSize()

Test case: (5)

Equivalence classes: non-existing key, partialSize entries

Robustness conditions: --

Boundary conditions: --

Bugs:

1. When cacheEntry is not full size, call remove() with a non-existing key will result in getting an NullPointerException.

**Cache.hitRate**

Input: *hits*, *misses*

Equivalence classes:

*Hits*: < 0, 0, > 0 INT\_MAX

*Misses*: <0, 0, >0, INT\_MAX

Test cases:

(1). hits = INT\_MAX, misses = INT\_MAX

(2). hits = 0, misses = 0

(3). hits = -1, misses = 1

(4). hits = 1, misses = -1

(5). hits = 3, misses = 5

(6). hits = 1, misses = 0

Failed tests:

1. Method: testMAXHitsMAXMisses()

Test case: (1)

Equivalence classes: hits = INT\_MAX, misses = INT\_MAX

Robustness conditions: hits = INT\_MAX, misses = INT\_MAX

Boundary conditions: --

1. Method: testZeroHitZeroMiss()

Test case: (2)

Equivalence classes: hits = 0, misses = 0

Robustness conditions: --

Boundary conditions: hits = 0, misses = 0

1. Method: testNegativeHitsPositiveMisses()

Test case: (3)

Equivalence classes: hits = -1, misses = 1

Robustness conditions: hits < 0

Boundary conditions: misses = 1 (off-by-one)

1. Method: testPositiveHitsNegativeMisses()

Similar as 3

1. Method: testSomeHitsSomeMisses()

Test case: (5)

Equivalence classes: hits > 0, misses > 0

Robustness conditions: --

Boundary conditions: --

1. Method: testAllHitsZeroMisses()

Test case: (6)

Equivalence classes: hits > 0, misses = 0

Robustness conditions: --

Boundary conditions: hits = 1, misses = 0

Bugs:

1. When cache is just initialized, that is, *hits* is 0 and *misses* is 0, the if we call hitRate() a NaN result is returned.
2. When *hits* is negative and *misses* is positive, no IllegalStateException is thrown.
3. When *misses* is negative and *hits* is positive, no IllegalStateException is thrown.
4. When hits or misses is INT\_MAX, or when hits + misses causes overflow, no IllegalStateException is thrown.
5. When misses and hits are positive, the result of hitRate() is not correct.

**Cache.growCache**

Input: *entries*, *initialSize*

Equivalence classes:

*initialSize*: <0, 0, >0, INT\_MAX

*entries*: 0 entry, 1 entry,partialSize entries, fullSize-1 entries, fullSize entries.

Test cases:

(1). initialSize = -10, 0 entry.

(2). initialSize = 0, 0 entry.

(3). initialSize = 8, 1 entry.

(4). initialSize = INT\_MAX, 7 entry.

(5). initialSize = 8, 8 entry.

(6). initialSize = 8, 7 entry.

Failed tests:

1. testNegativeInitialSizeEmptyCacheEntry()

Test case: (1)

Equivalence classes: initialSize < 0, 0 entry

Robustness conditions: initialSize < 0

Boundary conditions: 0 entry

1. testPositiveInitialSizeOneCacheEntries()

Test case: (3)

Equivalence classes: initialSize > 0, partialSize entry

Robustness conditions: --

Boundary conditions: 1 entry (off-by-one)

1. testMAXINTInitialSizeSomeCacheEntries()

Test case: (4)

Equivalence classes: initialSize = INT\_MAX, partialSize entry

Robustness conditions: initialSize = INT\_MAX

Boundary conditions: fullSize-1 entries (off-by-one)

1. testPositiveInitialSizeFullSizeCacheEntries()

Test case: (5)

Equivalence classes: initialSize > 0, fullSize entry

Robustness conditions: --

Boundary conditions: fullSize entry

1. testPositiveInitialSizeFullOffByOneCacheEntries()

Test case: (6)

Equivalence classes: initialSize > 0, partialSize entry

Robustness conditions: --

Boundary conditions: fullSize-1 entries (off-by-one)

Bugs:

1. When initialSize is negative, no appropriate exception message is thrown.
2. When initialSize of cacheEntry is positive, the call of growCache() does not increase the size of cacheEntry array.
3. growCache() does not handle the case of overflow(cacheEntry.length + initialSize).

**Cache.mostPopularKey**:

Input: *history*

Equivalence classes:

*history*: empty, one Popular Key, multiple Popular Keys

Test cases:

(1). Empty history.

(2). One popular key = “test”

(3). Two popular key: “test1”, “test2”

(4). First last key the same, others different

Bugs:

1. No bugs are found

**LRUCache.replace**

Input: *entries*

Equivalence classes:

*entries*: empty, 1 entry, some entries, fullSize entries(1. No tie in most recent, 2.ties in most recent)

Test cases:

(1). Empty entry.

(2). one entry.

(3). Some entries.

(4). Full size entries(no tie).

(5). Full size entries(tie).

Failed tests:

1. testFullCacheEntryFirstLeastRecent()

Test case: (4)

Equivalence classes: fullSize entries(no tie)

Robustness conditions: --

Boundary conditions: fullSize entries

1. testFullCacheEntryTies()

Test case: (5)

Equivalence classes: fullSize entries(tie)

Robustness conditions: --

Boundary conditions: fullSize entries

Bugs:

1. When cache entries is full, the call of replace() does not return the least resent visited entry correctly

**LFUCache.replace**

Input: *entries*

Equivalence classes:

*entries*: empty, one entry, some entries, fullSize entries (tie or not tie)

Test cases:

(1). Empty entry.

(2). one entry.

(3). Some entries.

(4). Full size entries(no tie).

1. least frequent entry is the first entry

2. least frequent entry is the last entry

3. least frequent entry is in other slots

(5). Full size entries(tie).

Failed tests:

1. testFullSizeEntriesMiddleCacheEntryLeastFrequent()

Test case: (4)

Equivalence classes: fullSize entries(no tie)

Robustness conditions: --

Boundary conditions: fullSize entries

1. testFullSizeEntriesLastCacheEntryLeastFrequent()

Similar as 1

1. testFullSizeEntriesWithTies()

Test case: (5)

Equivalence classes: fullSize entries(tie)

Robustness conditions: --

Boundary conditions: fullSize entries

Bugs:

1. When cache entries is full, the call of replace() does not return the least frequent visited entry correctly

**RandomCache.replace**

Input: *entries*

Equivalence classes:

*entries*: empty, one entry, some entries, fullSize entries

Test cases:

(1). Empty entry.

(2). one entry.

(3). Some entries.

(4). Full size entries

Bugs:

1. No bugs are found.

**Part 2:**

**Cache.get**

Input: *key*, *hits*, *misses*, *entries*, *history*

Equivalence classes:

*entries*: empty, one entry, fullSize-1 entries, fullSize entries

*key*: null, existing, non-existing key

*hits*: <0, 0, >0, INT\_MAX

*misses*: <0, 0, >0 INT\_MAX

*history*: empty, one entry, some entries

Test cases:

(1).null key, hits = -8, misses = -8, empty history entry, empty cache entries.

(2). Existing key, hits = 0, misses = 0, one history entry, one cache entry.

(3). Existing key, hits = 1, misses = 1, one history entry, full size cache entry.

(4). Existing key, hits = INT\_MAX, misses = INT\_MAX, some history entries, some cache entries.

(5). Non-existing key, hits = 1, misses = 1, some history entries, fullSize-1 cache entries.

Three test method: 1.LRUCache, 2.LFUCache, 3RandomCache

(6). Non-existing key, hits = 1, misses = 1, some history entries, full size cache entry.

Three test method: 1.LRUCache, 2.LFUCache, 3RandomCache

Failed tests:

1. testNullKeyNegativeHitsMissesEmptyCacheEntryEmptyHistory()

Test case: (1)

Equivalence classes: key = null, hits < 0, misses < 0, empty history, empty cache entries

Robustness conditions: key = null, hits < 0, misses < 0

Boundary conditions: empty history, empty cache entries

1. testExistingKeyZeroHitsMissesOneCacheEntryOneHistory()

Test case: (2)

Equivalence classes: existing key, hits = 0, misses = 0, one history, one cache entries

Robustness conditions: --

Boundary conditions: hits = 0, misses = 0, one history, one cache entries(off-by-one)

1. testExistingKeyPositiveHitsMissesFullCacheEntryOneHistory()

Test case: (3)

Equivalence classes: existing key, hits > 0, misses > 0, one history, full cache entries

Robustness conditions: --

Boundary conditions: hits = 1, misses = 1, one history, full cache entries

1. testExitingKeyPositiveHitsMissesSomeCacheEntriesSomeHistory()

Test case: (4)

Equivalence classes: existing key, hits = INT\_MAX, misses = INT\_MAX, some history, partialSize cache entries

Robustness conditions: hits = INT\_MAX, misses = INT\_MAX

Boundary conditions: --

1. testNonExitingKeySomeCacheEntriesLRU()
2. testNonExitingKeySomeCacheEntriesLFU()
3. testNonExitingKeySomeCacheEntriesRandom()

Test case: (5)

Equivalence classes: non-existing key, hits > 0, misses > 0, some history, partialSize cache entries

Robustness conditions: --

Boundary conditions: hits = 1, misses = 1, fullSize-1 cache entries

1. testNonExitingKeyFullCacheEntriesLRU()
2. testNonExitingKeyFullCacheEntriesLFU()
3. testNonExitingKeyFullCacheEntriesRandom()

Test case: (6)

Equivalence classes: non-existing key, hits > 0, misses > 0, some history, fullSize cache entries

Robustness conditions: --

Boundary conditions: hits = 1, misses = 1, fullSize cache entries

Bugs:

1. When key is null, the return value is not null as specified, also, a NullPointerException is thrown.
2. When hits/misses is INT\_MAX, an overflow will happen after a hit/miss.
3. In test case 4, when cacheEntries is not full and a cache miss happens, the call of get() will cause an NullPointerException. For LRU and LFU cache, there will always be an exception, for Random cache, it depends.
4. In test case 4, when Random cache entries is not full and a cache miss happens, if no exception is thrown, the return result is still wrong: the key is not null as expected.
5. When cache entry is full and a miss happens, the Eviction bugs are the same as recorded above in each cache’s replace method.
6. When cache entry is full and a miss happens, the access time of new added cache entry is not correct for all three caches.

**Part 3:**

Step3. False negatives :

1. testCalculateFare\_5()

fix: change expected result to -1, assertEquals(-1, result, 0.1);

1. testCalculateFare\_6()

fix: change expected result to -1, assertEquals(-1, result, 0.1);

1. testCalculateFare\_7()

fix: change expected result to -1, assertEquals(-1, result, 0.1);

1. testCalculateFare\_8()

fix: change expected result to -1, assertEquals(-1, result, 0.1);

1. testCalculateFare\_9()

fix: change expected result to -1, assertEquals(-1, result, 0.1);

1. testCalculateFare\_10()

fix: change expected result to -1, assertEquals(-1, result, 0.1);

1. testNumSeats\_1()

fix: change expected result to -1, assertEquals(-1, result, 0.1);

1. testNumSeats\_2()

fix: change expected result to -1, assertEquals(-1, result, 0.1);

1. testNumSeats\_3()

fix: change expected result to -1, assertEquals(-1, result, 0.1);

Step5.

In FareCalculatorTest:

1. Add test testCalculateFare\_Reduce15()

public void testCalculateFare\_Reduce15**()**

**throws** Exception **{**

FareCalculator fixture **=** **new** FareCalculator**();**

double price1 **=** 1.0**;**

double price2 **=** 502.0**;**

boolean isFreqFlier **=** **true;**

long departureTime **=** 1L**;**

int duration **=** 1**;**

double result **=** fixture**.**calculateFare**(**price1**,** price2**,** isFreqFlier**,** departureTime**,** duration**);**

// add additional test code here

assertEquals**(**-1**,** result**,** 0.1**);**

**}**

With arguments:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| price1 | price2 | isFreqFlier | departureTime | duration |
| 1 | 502 | TRUE | 1L | 1 |

Statements try to cover:

**if** **(**max **-** min **>** 500**)** **{**

price **=** **(**max **\*** .85**)** **+** min**;**

**}**

Branch try to cover:

**if** **(**max **-** min **>** 500**)**

Path conditions:

(price1 < price2 && price1 + 500 < price2) ||

(price1 > price2 && price1 > price2 + 500)

1. Add test testCalculateFare\_MoreThan14DaysFromNow()

@Test

public void testCalculateFare\_MoreThan14DaysFromNow**()**

**throws** Exception **{**

FareCalculator fixture **=** **new** FareCalculator**();**

double price1 **=** 1.0**;**

double price2 **=** 502.0**;**

boolean isFreqFlier **=** **true;**

long millisecondsPerDay **=** 1000 **\*** 60 **\*** 60 **\*** 24**;**

long departureTime **=** System**.**currentTimeMillis**()** **+** 15 **\*** millisecondsPerDay**;**

int duration **=** 1**;**

double result **=** fixture**.**calculateFare**(**price1**,** price2**,** isFreqFlier**,** departureTime**,** duration**);**

// add additional test code here

assertEquals**(**0.8**,** result**,** 0.1**);**

**}**

With arguments:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| price1 | price2 | isFreqFlier | departureTime | duration |
| 1 | 0 | TRUE | Now + 15Days | 1 |

Statements try to cover:

**if** **(**daysFromNow **>** 14**)** **{**

price **=** price **\*** 0.8**;**

**}**

Branch try to cover:

**if** **(**daysFromNow **>** 14**)**

Path conditions:

departureTime – timeOfNow > 14Days

1. Add testCalculateFare\_Between7and14DaysFromNow()

With arguments:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| price1 | price2 | isFreqFlier | departureTime | duration |
| 1 | 0 | TRUE | Now + 8Days | 1 |

Branch try to cover:

**else** **if** **(**daysFromNow **<** 7 **&&** **!**isFreqFlier**)**

Path conditions:

departureTime – timeOfNow <= 14Days && departureTime – timeOfNow >= 7Days

1. Unachievable statements and branches.

**if** **(**daysFromNow **<** 3 **&&** isFreqFlier**)** **{**

price **+=** 100.0 **\*** **(**3 **-** daysFromNow**);**

**}**

Because outside this branch is branch **else if (daysFromNow >= 7)**

If the outer branch is satisfied, the inner branch will not be satisfied

If the outer branch is not satisfied, the inner branch has no chance to be executed. So this branch is not reachable.

In SeatFinderTest:

1. Add testNumSeats\_NullState()

public void testNumSeats\_NullState**()**

**throws** Exception **{**

SeatFinder fixture **=** **new** SeatFinder**();**

byte**[]** state **=** **null;**

boolean windowOk **=** **true;**

boolean aisleOk **=** **true;**

boolean middleOk **=** **true;**

int maxRow **=** 1**;**

int result **=** fixture**.**numSeats**(**state**,** windowOk**,** aisleOk**,** middleOk**,** maxRow**);**

// add additional test code here

assertEquals**(-**1**,** result**);**

**}**

With arguments:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| state | windowOK | aisleOK | middleOK | maxRow |
| null | TRUE | TRUE | TRUE | 1 |

Branch try to cover:

**if** **(**state **==** **null** **||** maxRow **>** state**.**length **||** maxRow **<** 1**)** **return** 0**;**

Path conditions:

state == null

1. Add testNumSeats\_Window7()

public void testNumSeats\_Window7**()**

**throws** Exception **{**

SeatFinder fixture **=** **new** SeatFinder**();**

byte**[]** state **=** **new** byte**[]** **{(**byte**)** 0**,** **(**byte**)** 64**};;**

boolean windowOk **=** **true;**

boolean aisleOk **=** **true;**

boolean middleOk **=** **true;**

int maxRow **=** 1**;**

int result **=** fixture**.**numSeats**(**state**,** windowOk**,** aisleOk**,** middleOk**,** maxRow**);**

// add additional test code here

assertEquals**(**6**,** result**);**

**}**

With arguments:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| state | windowOK | aisleOK | middleOK | maxRow |
| {(byte) 0, (byte) 64} | TRUE | TRUE | TRUE | 1 |

Branch try to cover:

**if** **(**j **==** 1 **||** j **==** 7**)** aisleSeats**++;**

Path conditions:

One entry in state is (byte) 64