Lambda-Related Methods Directly in Lists and Maps

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Topics in This Section

• List
  – forEach (applies to all Iterables)
  – removeIf (applies to all Collections)
  – replaceAll
  – sort

• Map
  – forEach
  – computeIfAbsent (and compute, computeIfPresent)
  – merge
  – replaceAll

Overview

• Lists and other collections
  – Have methods that are shortcuts for very similar Stream methods
  – Often modify the existing List, unlike the Stream versions
  – With very large Lists, the new methods might have small performance advantages vs. the similar Stream methods

• Maps
  – Have methods that significantly extend their functionality vs. Java 7
  – No equivalent Stream methods
Lists: Overview of New Java 8 Methods

Summary

• forEach
  – Identical to forEach for Streams, but saves you from calling “stream()” first
• removeIf
  – Like filter with negation of the Predicate, but removeIf modifies the original List
• replaceAll
  – Like map, but replaceAll modifies the original List
  – Also, with replaceAll, the Function must map values to the same type as in List
• sort
  – Takes Comparator just like stream.sorted and Arrays.sort
forEach (Applies to All Iterables)

- **Basic syntax**
  - someList.forEach(someConsumer)
    - employeeList.forEach(System.out::println)

- **Equivalent Stream code**
  - someList.stream().forEach(someConsumer)
    - employeeList.stream().forEach(System.out::println)

- **Advantages**
  - Slightly shorter code
  - Same performance

- **Disadvantages**
  - None

removeIf (Applies to All Collections)

- **Basic syntax**
  - someList.removeIf(somePredicate)
    - stringList.removeIf(s -> s.contains("q"))

- **Equivalent Stream code**
  - someList = someList.stream().filter(somePredicate.negate()).collect(Collectors.toList())
    - stringList = stringList.stream().filter(s -> !s.contains("q")).collect(Collectors.toList())
      - If you want to be sure the new List is same concrete type as old one, then you should do
        ... collect(Collectors.toCollection(YourListType::new))

- **Advantages**
  - Shorter code if you want to modify the original List
  - Possible slight performance gain for very large Lists

- **Disadvantages**
  - Longer code if you want to result to be new List
replaceAll

- **Basic syntax**
  - `someList.replaceAll(someUnaryOperator)`
    - `stringList.replaceAll(String::toUpperCase)`

- **Equivalent Stream code**
  - `someList = someList.stream().map(someFunction)`
    - `.collect(Collectors.toList())`
    - `stringList = stringList.stream().map(String::toUpperCase).collect(Collectors.toList())`

- **Advantages**
  - Shorter code if you want to modify the original List
  - Possible slight performance gain for very large Lists

- **Disadvantages**
  - Longer code if you want to result to be new List
  - `replaceAll` must map to same type as entries in original List, whereas `map` can produce streams of totally different types

sort

- **Idea**
  - `someList.sort(someComparator)`
    - `employeeList.sort(Comparator.comparing(Employee::getLastName))`

- **Equivalent Stream method**
  - `someList = someList.stream().sorted(someComparator)`
    - `.collect(Collectors.toList())`
    - `stringList = stringList.stream().sorted(Comparator.comparing(Employee::getLastName))` `.collect(Collectors.toList())`

- **Advantages**
  - Shorter code if you want to modify the original List
  - Large performance gain for very large LinkedLists (not for ArrayLists)

- **Disadvantages**
  - Longer code if you want to result to be new List
Lists: Performance Comparisons

Overview

• Questions
  – Because removeIf, replaceAll, and sort modify the original List, will they be faster than streaming the List and accumulating the result into a new List?

• Preview of answers
  – removeIf: no
  – replaceAll: possibly yes for LinkedList, no for ArrayList
  – sort: possibly yes for LinkedList, no for ArrayList

• Caution
  – Results did not show clear trends; they should be viewed skeptically
    • Results may depend on memory usage and details of current Java release
  – What is clear is that for sizes below about a million entries, there was no measurable performance difference, at least with the current Java release
    • Conclusion: use the List methods for convenience (because they modify existing List), not for performance reasons
public class PerformanceTests {
    private static LinkedList<Integer> list1;
    private static ArrayList<Integer> list2;
    private static LinkedList<Integer> list3;
    private static ArrayList<Integer> list4;
    private static String message =
            "%s entries in %s with %,d elements.%n";

    private static void initializeLists(int size) {
        list1 = new LinkedList<>();
        fillList(list1, size);
        list2 = new ArrayList<>(size);
        fillList(list2, size);
        list3 = new LinkedList<>();
        fillList(list3, size);
        list4 = new ArrayList<>();
        fillList(list4, size);
    }

    private static void fillList(List<Integer> nums, int size) {
        for (int i = 0; i < size; i++) {
            nums.add(i);
        }
    }
}
private static void profileRemoveIf() {
    int size = 1_000_000;
    for(int i=0; i<4; i++) {
        initializeLists(size);
        Predicate<Integer> isEven = n -> n%2 == 0;
        Predicate<Integer> isOdd = n -> n%2 != 0;
        System.out.printf(message, "Removing even", "LinkedList", size);
        Op.timeOp(() -> list1.removeIf(isEven));
        System.out.printf(message, "Removing even", "ArrayList", size);
        Op.timeOp(() -> list2.removeIf(isEven));
        System.out.printf(message, "Streaming and filtering even", "LinkedList", size);
        Op.timeOp(() -> list3 = list3.stream().filter(isOdd)
                  .collect(Collectors.toCollection(LinkedList::new)));
        System.out.printf(message, "Streaming and filtering even", "ArrayList", size);
        Op.timeOp(() -> list4 = list4.stream().filter(isOdd)
                  .collect(Collectors.toCollection(ArrayList::new)));
        size = size * 2;
        System.out.println();
    }
}"
replaceAll: Code

```java
private static void profileReplaceAll() {
    int size = 1_000_000;
    for(int i=0; i<4; i++) {
        initializeLists(size);
        UnaryOperator<Integer> doubleIt = n -> n*2;
        System.out.printf(message, "Doubling", "LinkedList", size);
        Op.timeOp(() -> list1.replaceAll(doubleIt));
        System.out.printf(message, "Doubling", "ArrayList", size);
        Op.timeOp(() -> list2.replaceAll(doubleIt));
        System.out.printf(message, "Streaming and doubling", "LinkedList", size);
        Op.timeOp(() -> list3 = list3.stream().map(doubleIt)
                .collect(Collectors.toCollection(LinkedList::new)));
        System.out.printf(message, "Streaming and doubling", "ArrayList", size);
        Op.timeOp(() -> list4 = list4.stream().map(doubleIt)
                .collect(Collectors.toCollection(ArrayList::new)));
        size = size * 2;
        System.out.println();
    }
}
```

replaceAll: Representative Results

Doubling entries in LinkedList with 1,000,000 elements.
Elapsed time: 0.484 seconds.
Doubling entries in ArrayList with 1,000,000 elements.
Elapsed time: 0.013 seconds.
Streaming and doubling entries in LinkedList with 1,000,000 elements.
Elapsed time: 0.173 seconds.
Streaming and doubling entries in ArrayList with 1,000,000 elements.
Elapsed time: 0.026 seconds.

... (Similar for 2,000,000 and 4,000,000)

Doubling entries in LinkedList with 8,000,000 elements.
Elapsed time: 0.072 seconds.
Doubling entries in ArrayList with 8,000,000 elements.
Elapsed time: 0.554 seconds.
Streaming and doubling entries in LinkedList with 8,000,000 elements.
Elapsed time: 7.746 seconds.
Streaming and doubling entries in ArrayList with 8,000,000 elements.
Elapsed time: 1.739 seconds.

Results were highly variable, but average results seemed worse for streaming case with LinkedList when List sizes were very large. No measurable difference for when List sizes were 2 million or less. Might depend on specific Java release.
private static void profileSort() {
    int size = 1_000_000;
    for(int i=0; i<4; i++) {
        initializeLists(size);
        Comparator<Integer> evensFirst = (i1, i2) -> (i1 % 2) - (i2 % 2);
        System.out.printf(message, "Sorting", "LinkedList", size);
        Op.timeOp(() -> list1.sort(evensFirst));
        System.out.printf(message, "Sorting", "ArrayList", size);
        Op.timeOp(() -> list2.sort(evensFirst));
        System.out.printf(message, "Streaming and sorting", "LinkedList", size);
        Op.timeOp(() -> list3 = list3.stream().sorted(evensFirst)
                    .collect(Collectors.toCollection(LinkedList::new)));
        System.out.printf(message, "Streaming and sorting", "ArrayList", size);
        Op.timeOp(() -> list4 = list4.stream().sorted(evensFirst)
                    .collect(Collectors.toCollection(ArrayList::new)));
        size = size * 2;
        System.out.println();
    }
}

sort: Representative Results

Sorting entries in LinkedList with 1,000,000 elements.
Elapsed time: 0.117 seconds.
Sorting entries in ArrayList with 1,000,000 elements.
Elapsed time: 0.037 seconds.
Streaming and sorting entries in LinkedList with 1,000,000 elements.
Elapsed time: 0.064 seconds.
Streaming and sorting entries in ArrayList with 1,000,000 elements.
Elapsed time: 0.058 seconds.
...
(2,000,000 and 4,000,000 showed slightly worse for streaming with LinkedList)

Sorting entries in LinkedList with 8,000,000 elements.
Elapsed time: 0.410 seconds.
Sorting entries in ArrayList with 8,000,000 elements.
Elapsed time: 0.283 seconds.
Streaming and sorting entries in LinkedList with 8,000,000 elements.
Elapsed time: 8.637 seconds.
Streaming and sorting entries in ArrayList with 8,000,000 elements.
Elapsed time: 0.610 seconds.

Results were highly variable, but average results seemed worse for streaming case with LinkedList when List sizes were very large.
Maps: Overview of New Java 8 Methods

Summary

- **forEach(function)**
  - Similar to forEach for Stream and List, except function takes *two* arguments: the key and the value

- **replaceAll(function)**
  - For each Map entry, passes the key and the value to the function, takes the output, and replaces the old value with it
    - Similar to replaceAll for List, except function takes *two* arguments: key and value

- **merge(key, initialValue, function)**
  - If no value is found for the key, store the initial value
  - Otherwise pass old value and initial value to the function, and overwrite current result with that output

- **computeIfAbsent(key, function)**
  - If value is found for the key, return it
  - Otherwise pass the key to the function, store the output in Map, and return it
forEach and replaceAll

• forEach(function): idea
  – For each Map entry, passes the key and the value to the function

• Mini example
  ```java
  map.forEach((key, value) ->
    System.out.printf("(%s,%s)\n", key, value));
  ```

• replaceAll(function): idea
  – For each Map entry, passes the key and the value to the function, then replaces existing value with that output

• Mini example
  ```java
  shapeAreas.replaceAll((shape, area) -> Math.abs(area));
  ```
public class MapUtils {
    public static <K,V> void printMapEntries(Map<K,V> map) {
        map.forEach((key, value) -> System.out.printf("(%s,%s)%n", key, value));
    }
}

Example Usage

public class NumberMap {
    private static Map<Integer,String> numberMap = new HashMap<>();

    static {
        numberMap.put(1, "uno");
        numberMap.put(2, "dos");
        numberMap.put(3, "tres");
    }

    public static void main(String[] args) {
        MapUtils.printMapEntries(numberMap);
        numberMap.replaceAll((number, word) -> word.toUpperCase());
        MapUtils.printMapEntries(numberMap);
    }
}
merge(key, initialValue, function)

- **Idea**
  - Lets you update existing values
    - If no value is found for the key, store the initial value
    - Otherwise pass old value and initial value to the function, and overwrite current result with that updated result

- **Mini example** (creates message or adds it on end of old one)
  ```java
  messages.merge(key, message, (old, initial) -> old + initial);
  ```
  - Or, equivalently
    ```java
    messages.merge(key, message, String::concat);
    ```
merge: Example Usage

• Idea
  – Given an array of ints, produce Map that has counts of how many times each entry appeared
  – For example, if you have a very large array of grades on exams (all from 0-100), you can use this to sort them in O(N), instead of a comparison-based sort that is O(N log(N)).

• Code snippet
  Map<Integer,Integer> counts = new HashMap<>();
  for(int num: nums) {
    counts.merge(num, 1, (old, initial) -> old + 1);
  }

Full Code and Results

public class CountEntries {
    public static void main(String[] args) {
        int[] nums = { 1, 2, 3, 3, 3, 3, 4, 2, 2, 1 };
        MapUtils.printMapEntries(countEntries(nums));
    }

    public static Map<Integer,Integer> countEntries(int[] nums) {
        Map<Integer,Integer> counts = new HashMap<>();
        for(int num: nums) {
            counts.merge(num, 1, (old, initial) -> old + 1);
        }
        return(counts);
    }
}
computeIfAbsent(key, function)

• **Idea**
  – Lets you remember previous computations
    • If value is found for the key, return it
    • Otherwise pass the key to the function, store the output in Map, and return it
  – If this technique is applied to entire result of a method call, it is known as *memoization* (like memorization without the “r”). Memoization applied to recursive functions that have overlapping subproblems results in automatic dynamic programming and can provide huge performance gains.

• **General format for 1-argument methods**
  – First, make a Map that maps argument types to return types. Then:

    ```java
def memoizedMethod(arg) {
      return map.computeIfAbsent(arg, val -> codeForOriginalMethod(val));
    }
```
Simple Example: Prime Numbers

• Idea
  – Use my Primes utility class to find primes of a given size. Once you find an n-digit prime, remember it and return it next time that you are asked for one of that size.

• Original version
  public static BigInteger findPrime1(int numDigits) {
    return(Primes.findPrime(numDigits));
  }
  – Finding large (e.g., 200-digit) primes is expensive, so if you do not need new results each time, this is wasteful.

• Memoized version (after making Map<Integer,BigInteger>)
  public static BigInteger findPrime(int numDigits) {
    return(primes.computeIfAbsent(numDigits, n -> Primes.findPrime(n)));
  }
  – First time you ask for prime of size n: calculates it. Second time: returns old result.

Full Code for Memoized Version

public class PrimeMap {
  private static Map<Integer,BigInteger> primes = new HashMap<>();

  public static void main(String[] args) {
    List<Integer> lengths = Arrays.asList(2, 10, 20, 100, 200);
    System.out.println("First pass");
    lengths.forEach(size ->
      System.out.printf(" %3s-digit prime: %s.%n", size, findPrime(size));
    System.out.println("Second pass");
    lengths.forEach(size ->
      System.out.printf(" %3s-digit prime: %s.%n", size, findPrime(size));
  }

  public static BigInteger findPrime(int numDigits) {
    return(primes.computeIfAbsent(numDigits, n -> Primes.findPrime(n)));
  }
}
Results

First pass
   2-digit prime: 37.
   10-digit prime: 9865938581.
   20-digit prime: 81266731015996542377.
   100-digit prime: 1303427690327864321962160479063291713409714810200274897329783052109801136752356902322620555470787489761.
   200-digit prime: 857905274073898857594770480875369911725087313464765980183633205764337881172327732861224838697095703054164862223715266374825528657644821099376025167527875033358671953470058032952063785626990620878858700026709421376853927517916990713897157838832661190518934301327725403763719814279140010843000372638489855650874013510801871104364362859613051097381953684590166872480267040343758734229783725262825553563842713677774256306274023019799240345273056137396050648753532429371197757276310446146890967966010036173432831176327072926927698767587257401033394831561.

Second pass
   2-digit prime: 37.
   10-digit prime: 9865938581.
   20-digit prime: 81266731015996542377.
   100-digit prime: 1303427690327864321962160479063291713409714810200274897329783052109801136752356902322620555470787489761.
   200-digit prime: 857905274073898857594770480875369911725087313464765980183633205764337881172327732861224838697095703054164862223715266374825528657644821099376025167527875033358671953470058032952063785626990620878858700026709421376853927517916990713897157838832661190518934301327725403763719814279140010843000372638489855650874013510801871104364362859613051097381953684590166872480267040343758734229783725262825553563842713677774256306274023019799240345273056137396050648753532429371197757276310446146890967966010036173432831176327072926927698767587257401033394831561.

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Example 2: Fibonacci Numbers

- **Idea**
  - Make a recursive function to calculate numbers in the sequence 0, 1, 1, 2, 3, 5, 8...
  - \( \text{Fib}(0) = 0 \)
  - \( \text{Fib}(1) = 1 \)
  - \( \text{Fib}(n) = \text{Fib}(n-1) + \text{Fib}(n-2) \)

- **Problem**
  - The straightforward recursive version has overlapping subproblems: when computing \( \text{Fib}(n-1) \), it computes \( \text{Fib}(n-2) \), yet it repeats that computation when finding \( \text{Fib}(n-2) \) directly. This results in exponential complexity.

- **Solutions**
  - In this case, you can build up from the bottom with an iterative version.
    - But, for many other problems, it is hard to find non-recursive solution, and that solution is far more complex than the iterative one. E.g., recursive-descent parsing, finding change with fewest coins, longest common substring, many more.
  - Better solution: use recursive version, then memoize it with computeIfAbsent
public static int fib1(int n) {
    if (n <= 1) {
        return(n);
    } else {
        return(fib1(n-1) + fib1(n-2));
    }
}

private static Map<Integer,Integer> fibMap = new HashMap<>();

public static int fib(int num) {
    return
    fibMap.computeIfAbsent(num, n -> {
        if (n <= 1) {
            return(n);
        } else {
            return(fib(n-1) + fib(n-2));
        }
    });
}

An even better version would make the output long or even BigInteger, since Fibonacci numbers will quickly overflow ints.
public static void profileFib() {
    for(i=0; i<47; i++) {
        Op.timeOp(() -> System.out.printf("fib1(%s) = %s.%n", i, fib1(i)));
        Op.timeOp(() -> System.out.printf("fib(%s) = %s.%n", i, fib(i)));
    }
}

fib1(0) = 0.
Elapsed time: 0.001 seconds.
fib(0) = 0.
Elapsed time: 0.001 seconds.
fib1(1) = 1.
Elapsed time: 0.000 seconds.
fib(1) = 1.
Elapsed time: 0.000 seconds.
...
fib1(44) = 701408733.
Elapsed time: 3.269 seconds.
fib(44) = 701408733.
Elapsed time: 0.000 seconds.
fib1(45) = 1134903170.
Elapsed time: 5.293 seconds.
fib(45) = 1134903170.
Elapsed time: 0.000 seconds.
fib1(46) = 1836311903.
Elapsed time: 8.572 seconds.
fib(46) = 1836311903.
Elapsed time: 0.000 seconds.
Summary

• Lists
  – forEach
    • Identical to forEach for Streams, but saves you from calling “stream()” first
  – removeIf
    • Like filter with negation of the Predicate, but removeIf modifies the original List
  – replaceAll
    • Like map, but replaceAll modifies the original List
  – sort
    • Takes Comparator just like stream.sorted and Arrays.sort, and modifies original List

• Maps
  – forEach(function) and replaceAll(function)
    • Similar to versions for List, except function takes two arguments: the key and the value
  – merge(key, initialValue, function)
    • Lets you update old values
  – computeIfAbsent(key, function)
    • Lets you make memoized functions that remember previous calculations

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