Streams in Java 8: Part 2

Originals of slides and source code for examples: http://courses.coreservlets.com/Course-Materials/java.html
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Topics in This Section

- **More stream methods**
  - limit, skip
  - sorted, min, max , distinct
  - noneMatch, allMatch, anyMatch, count
- **Number-specialized streams**
  - IntStream, DoubleStream, LongStream
- **Reduction operations**
  - reduce(starterValue, binaryOperator)
  - reduce(binaryOperator).orElse(...)
  - min, max, sum, average

Operations that Limit the Stream Size: limit, skip

Limiting Stream Size

- **Big ideas**
  - limit(n) returns a Stream of the first n elements.
  - skip(n) returns a Stream starting with element n (i.e., it throws away the first n elements)
  - Both are short-circuit operations. E.g., if you have a 1000-element stream and then do the following, it applies fn1 exactly 10 times, evaluates pred exactly 10 times, and applies fn2 at most 10 times

```
strm.map(fn1).filter(pred).map(fn2).limit(10)
```

- **Quick examples**
  - First 10 elements
    - `someLongStream.limit(10)`
  - Last 15 elements
    - `twentyElementStream.skip(5)`

limit and skip: Example

- **Code**

```
List<Employee> googlers = EmployeeSamples.getGooglers();
List<String> emps = googlers.stream()
                            .map(Person::getFirstName)
                            .limit(8)
                            .skip(2)
                            .collect(Collectors.toList());
System.out.printf("Names of 6 Googlers: %s.%n", emps);
```

- **Point**
  - getFirstName called 6 times, even if Stream is very large
- **Results**

```
Names of 6 Googlers: [Eric, Nikesh, David, Patrick, Susan, Peter].
```

Operations that use Comparisons: sorted, min, max, distinct

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Comparisons: Big Ideas

- **sorted**
  - Sorting Streams is more flexible than sorting arrays because you can do filter and mapping operations before and/or after
    - Note the inconsistency that method is called sorted, not sort
- **min and max**
  - It is faster to use min and max than to sort forward or backward, then take first element
- **distinct**
  - distinct uses equals as its comparison

Comparisons: Quick Examples

- **Sorting by salary**

```
empStream.sorted((e1, e2) -> e1.getSalary() - e2.getSalary())
```

- **Richest Employee**

```
empStream.max((e1, e2) -> e1.getSalary() - e2.getSalary()).get()
```

- **Words with duplicates removed**

```
stringStream.distinct()
```

Sorting

- **Big ideas**
  - The advantage of someStream.sorted(…) over Arrays.sort(…) is that with Streams you can first do operations like map, filter, limit, skip, and distinct
  - Doing limit or skip after sorting does *not* short-circuit in the same manner as in the previous section
    - Because the system does not know which are the first or last elements until after sorting
  - If the Stream elements implement Comparable, you may omit the lambda and just use someStream.sorted(). Rare.
- **Supporting code from Person class**

```
public int firstNameComparer(Person other) {
  System.out.println("Comparing first names");
  return(firstName.compareTo(other.getFirstName()));
}
```

Sorting by Last Name: Example

- **Code**

```
List<Integer> ids = Arrays.asList(9, 11, 10, 8);
List<Employee> emps1 =
  ids.stream().map(EmployeeSamples::findGoogler)
             .sorted((e1, e2) -> e1.getLastName().compareTo(e2.getLastName()))
             .collect(Collectors.toList());
System.out.printf("Googlers with ids %s sorted by last name: %s.%n", ids, emps1);
```

- **Results**

```
Googlers with ids [9, 11, 10, 8] sorted by last name:
  [Gilad Bracha [Employee#11 $600,000],
   Jeffrey Dean [Employee#9 $800,000],
   Sanjay Ghemawat [Employee#10 $700,000],
   Peter Norvig [Employee#8 $900,000]].
```

Sorting by First Name then Limiting: Example

- **Code**

```
List<Employee> emps3 =
  sampleEmployees().sorted(Person::firstNameComparer)
                   .limit(2)
                   .collect(Collectors.toList());
System.out.printf("Employees sorted by first name: %s.%n",
                  emps3);
```

- **Point**
  - The use of limit(2) does *not* reduce the number of times firstNameComparer is called (vs. no limit at all)
- **Results**

```
Employees sorted by first name:
  [Amy Accountant [Employee#25 $85,000],
   Archie Architect [Employee#16 $144,444]].
```

min and max

- **Big ideas**
  - min and max use the same type of lambdas as sorted, letting you flexibly find the first or last elements based on various different criteria
    - min and max could be easily reproduced by using reduce, but this is such a common case that the short-hand reduction methods (min and max) are built in
  - min and max both return an Optional
  - Unlike with sorted, you must provide a lambda, regardless of whether or not the Stream elements implement Comparable
- **Performance implications**
  - Using min and max is faster than sorting in forward or reverse order, then using findFirst
    - min and max are O(n), sorted is O(n log n)

min: Example

- **Code**

```
Employee alphabeticallyFirst =
  ids.stream().map(EmployeeSamples::findGoogler)
             .min((e1, e2) ->
                     e1.getLastName()
                       .compareTo(e2.getLastName()))
             .get();
System.out.printf
    ("Googler from %s with earliest last name: %s.%n",
     ids, alphabeticallyFirst);
```

- **Results**

```
Googler from [9, 11, 10, 8] with earliest last name:
  Gilad Bracha [Employee#11 $600,000].
```

max: Example

- **Code**

```
Employee richest =
  ids.stream().map(EmployeeSamples::findGoogler)
              .max((e1, e2) -> e1.getSalary() -
                               e2.getSalary())
              .get();
System.out.printf("Richest Googler from %s: %s.%n",
                  ids, richest);
```

- **Results**

```
Richest Googler from [9, 11, 10, 8]:
  Peter Norvig [Employee#8 $900,000].
```

distinct: Example

- **Code**

```
List<Integer> ids2 = Arrays.asList(9, 10, 9, 10, 9, 10);
List<Employee> emps4 =
  ids2.stream().map(EmployeeSamples::findGoogler)
              .distinct()
              .collect(Collectors.toList());
System.out.printf("Unique Googlers from %s: %s.%n", ids2, emps4);
```

- **Results**

```
Unique Googlers from [9, 10, 9, 10, 9, 10]:
  [Jeffrey Dean [Employee#9 $800,000],
   Sanjay Ghemawat [Employee#10 $700,000]].
```

Operations that Check Matches: allMatch, anyMatch, noneMatch, count

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Checking Matches

- **Big ideas**
  - allMatch, anyMatch, and noneMatch take a Predicate and return a boolean
  - They stop processing once an answer can be determined
    - E.g., if the first element fails the Predicate, allMatch would immediately return false and skip checking other elements
  - count simply returns the number of elements
    - count is a terminal operation, so you cannot first count the elements, then do a further operation on the same Stream
- **Quick examples**
  - Is there at least one rich dude?
    - employeeStream.anyMatch(e -> e.getSalary() > 500_000)
  - How many employees match the criteria?
    - employeeStream.filter(somePredicate).count()

Matches: Examples

- **Code**

```
List<Employee> googlers = EmployeeSamples.getGooglers();
boolean isNobodyPoor = googlers.stream().noneMatch(e -> e.getSalary() < 200_000);
Predicate<Employee> megaRich = e -> e.getSalary() > 7_000_000;
boolean isSomeoneMegaRich = googlers.stream().anyMatch(megaRich);
boolean isEveryoneMegaRich = googlers.stream().allMatch(megaRich);
long numberMegaRich = googlers.stream().filter(megaRich).count();
System.out.printf("Nobody poor? %s.%n", isNobodyPoor);
System.out.printf("Someone mega rich? %s.%n", isSomeoneMegaRich);
System.out.printf("Everyone mega rich? %s.%n", isEveryoneMegaRich);
System.out.printf("Number mega rich: %s.%n", numberMegaRich);
```

- **Results**

```
Nobody poor? true.
Someone mega rich? true.
Everyone mega rich? false.
Number mega rich: 3.
```

Number-Specialized Streams

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IntStream

- **Big idea**
  - A specialization of Stream that makes it easier to deal with ints. Does not extend Stream, but instead extends BaseStream, on which Stream is also built.
- **Motivation**
  - Simpler methods
    - min(), max(), sum(), average()
      - min, max, sum return int, average returns OptionalDouble
  - Output as int[]
    - toArray()
  - Can make IntStream from int[] instead of Integer[]
- **Similar interfaces**
  - DoubleStream
  - LongStream

Quick Examples

- **Cost of fleet of cars**

```
double totalCost =
  carList.stream().mapToDouble(Car::getPrice).sum();
```

- **Total population in region**

```
int population = countryList.stream()
                            .filter(Utils::inRegion)
                            .mapToInt(Country::getPopulation)
                            .sum();
```

- **Average salary**

```
double averageSalary =
  employeeList.stream()
              .mapToDouble(Employee::salary)
              .average()   // average returns OptionalDouble,
              .orElse(-1); // not double
```

Making an IntStream

- **regularStream.mapToInt**
  - Assume that getAge returns an int. Then, the following produces an IntStream
    - personList.stream().mapToInt(Person::getAge)
- **IntStream.of**
  - IntStream.of(int1, int2, int2)
  - IntStream.of(intArray)
    - Can also use Arrays.stream for this
- **IntStream.range, IntStream.rangeClosed**
  - IntStream.range(5, 10)
- **Random.ints**
  - new Random().ints(), anyInstanceOfRandom.ints()
    - An “infinite” IntStream of random numbers. But you can apply limit to make a finite stream, or use findFirst
    - There are also versions where you give range of ints or size of stream

IntStream Methods

- **Specific to number streams**
  - min, max
    - No arguments, output is int
  - sum
    - No arguments, output is int
  - average
    - No arguments, output is OptionalDouble
  - toArray
    - No arguments, output is int[]
- **Similar to regular streams**
  - map, mapToDouble, mapToObject
    - Function for map must produce int
  - filter, reduce, forEach, limit, skip, parallel, anyMatch, etc.
    - Most methods from Stream, but IntStream is *not* a subclass of Stream

Similar Stream Specializations

- **DoubleStream**
  - Creating
    - `regularStream.mapToDouble`
    - `DoubleStream.of`
    - `someRandom.doubles`
  - Methods
    - min, max, sum, average (no args, output is double)
    - toArray (no args, output is double[])
- **LongStream**
  - Creating
    - regularStream.mapToLong, LongStream.of, someRandom.longs
  - Methods
    - min, max, sum, average (no args, output is long)
    - toArray (no args, output is long[])

Common Incorrect Attempts at Making IntStream

- **Stream.of(int1, int2, int3)**

```
Stream.of(1, 2, 3, 4)
```

  - Builds Stream<Integer>, not IntStream
- **Stream.of(integerArray)**

```
Integer[] nums = { 1, 2, 3, 4 };
Stream.of(nums)
```

  - Builds Stream<Integer>, not IntStream
- **Stream.of(intArray)**

```
int[] nums = { 1, 2, 3, 4 };
Stream.of(nums)
```

  - Builds Stream containing one element, where that one element is an int[]
  - See analogous code on next slide

Building Stream Containing Array: Analogous Example

```
public class UseArgs {
  public static int firstNumber(int... nums) {
    return(nums[0]);
  }

  public static Object firstObject(Object... objects) {
    return(objects[0]);
  }
}
```

Analogous Example Continued

```
public class SupplyArgs {
  public static void main(String[] args) {
    int[] nums = { 1, 2, 3 };
    int result1 = UseArgs.firstNumber(1, 2, 3);
    System.out.printf("result1: %s%n", result1);
    int result2 = UseArgs.firstNumber(nums);
    System.out.printf("result2: %s%n", result2);
    Object result3 = UseArgs.firstObject(1, 2, 3);
    System.out.printf("result3: %s%n", result3);
    Object result4 = UseArgs.firstObject(nums);
    System.out.printf("result4: %s%n", result4);
  }
}
```

```
result1: 1
result2: 1
result3: 1
result4: [I@659e0bfd
```

The reduce method and Related Reduction Operations

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Reduction Operations

- **Big idea**
  - Reduction operations take a Stream<T>, and combine or compare the entries to produce a single value of type T
- **Trivial examples**
  - findFirst().orElse(…)
  - findAny().orElse(…)
- **Examples in Stream**
  - min(comparator), max(comparator)
  - reduce(starterValue, binaryOperator)
  - reduce(binaryOperator).orElse(…)
- **Examples in IntStream**
  - min(), max(), sum(), average()

reduce: Big Idea

- **Repeated combining**
  - You start with a seed (identity) value, combine this value with the first entry of the Stream, combine the result with the second entry of the Stream, and so forth
    - reduce is particularly useful when combined with map or filter
    - Works properly with parallel streams if operator is associative and has no side effects
- **reduce(starter, binaryOperator)**
  - Takes starter value and BinaryOperator. Returns result directly.
- **reduce(binaryOperator)**
  - Takes BinaryOperator, with no starter. It starts by combining first 2 values with each other. Returns an Optional.

reduce: Quick Examples

- **Maximum of numbers**

```
nums.stream().reduce(Double.MIN_VALUE, Double::max)
```

- **Product of numbers**

```
nums.stream().reduce(1, (n1, n2) -> n1 * n2)
```

- **Concatenation of strings**

```
letters.stream().reduce("", String::concat);
```

Concatenating Strings: More Details

- **Code**

```
List<String> letters = Arrays.asList("a", "b", "c", "d");
String concat = letters.stream().reduce("", String::concat);
System.out.printf("Concatenation of %s is %s.%n", letters, concat);
```

This is the starter (identity) value. It is combined with the first entry in the Stream.

This is the BinaryOperator. It is the same as (s1, s2) -> s1 + s2. It concatenates the seed value with the first Stream entry, concatenates that resultant String with the second Stream entry, and so forth.

- **Results**

```
Concatenation of [a, b, c, d] is abcd.
```

Concatenating Strings: Variations

- **Data**
  - `List<String> letters = Arrays.asList("a", "b", "c", "d");`
- **Various reductions**
  - `letters.stream().reduce("", String::concat);`
    → `"abcd"`
    - Remember that String::concat here is the same as if you had written the lambda (s1,s2) -> s1+s2
  - `letters.stream().reduce("", (s1,s2) -> s2+s1);`
    → `"dcba"`
    - This just reverses the order of the s1 and s2 in the concatenation
  - `letters.stream().reduce("", (s1,s2) -> s2.toUpperCase() + s1.toUpperCase());`
    → `"DCBA"`

Finding “Biggest” Employee

- **Code**

```
Employee poorest = new Employee("None", "None", -1, -1);
BinaryOperator<Employee> richer = (e1, e2) -> {
  return(e1.getSalary() >= e2.getSalary() ? e1 : e2);
};
Employee richestGoogler = googlers.stream().reduce(poorest, richer);
System.out.printf("Richest Googler is %s.%n", richestGoogler);
```

- **Results**

```
Richest Googler is Larry Page [Employee#1 $9,999,999].
```

reduce uses the BinaryOperator to combine the starter value with the first Stream entry, then combines that result with the second Stream entry, and so forth.

Finding Sum of Salaries: Two Alternatives

- **Alternative 1**
  - Use mapToInt, then use sum()
- **Alternative 2**
  - Use map, then use reduce

Finding Sum of Salaries

```
public class SalarySum {
  private static List<Employee> googlers = EmployeeSamples.getGooglers();

  public static int sum1() {
    return googlers.stream()
                   .mapToInt(Employee::getSalary)
                   .sum();
  }

  public static int sum2() {
    return googlers.stream()
                   .map(Employee::getSalary)
                   .reduce(0, Integer::sum);
  }
}
```

Finding Smallest Salary: Three Alternatives

- **Alternative 1**
  - Use mapToInt, then use min()
- **Alternative 2**
  - Use map, then use min(comparator)
- **Alternative 3**
  - Use map, then use reduce

Finding Smallest Salary

```
public static int min1() {
  return googlers.stream().mapToInt(Employee::getSalary)
                          .min()
                          .orElse(Integer.MAX_VALUE);
}

public static int min2() {
  return googlers.stream().map(Employee::getSalary)
                          .min((n1, n2) -> n1 - n2)
                          .orElse(Integer.MAX_VALUE);
}

public static int min3() {
  return googlers.stream().map(Employee::getSalary)
                          .reduce(Integer.MAX_VALUE, Integer::min);
}
```

Wrap-Up

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Summary: More Stream Methods

- **Limiting Stream size**
  - limit, skip
    - Can trigger short-circuiting
- **Using comparisons**
  - sorted, min, max, distinct
    - Must traverse entire stream
- **Finding matches**
  - allMatch, anyMatch, noneMatch
    - Can be short-circuited
  - count
    - Must traverse entire stream

Summary: Specializations and Reductions

- **Reduction operations on Stream<T>**
  - min(comparator)
  - max(comparator)
  - reduce(starterValue, binaryOperator)
  - reduce(binaryOperator).orElse(…)
- **IntStream and DoubleStream**
  - regularStream.mapToInt, regularStream.mapToDouble
  - IntStream.of, DoubleStream.of
- **Reduction operations on IntStream and DoubleStream**
  - min(), max(), sum(), average()

Questions?

More info:

http://courses.coreservlets.com/Course-Materials/java.html – General Java programming tutorial

http://www.coreservlets.com/java-8-tutorial/ – Java 8 tutorial

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