Streams in Java 8: Part 2

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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

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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)
- `limit` is a short-circuit operation. E.g., if you have a 1000-element stream and then do the following, it applies `funct1` exactly 10 times, evaluates `pred` at least 10 times (until 10 elements pass), and applies `funct2` at most 10 times
  \[
  \text{strm.map}(\text{funct1}).\text{filter}(\text{pred}).\text{map}(\text{funct2}).\text{limit}(10)
  \]

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

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**limit and skip: Example**

**Code**

```java
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

Comparisons: Big Ideas

- **sorted**
  - sorted with a Comparator works just like Arrays.sort, discussed earlier
  - sorted with no arguments works only if the Stream elements implement Comparable
  - 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
  - min and max take a Comparator as an argument

- **distinct**
  - distinct uses equals as its comparison
Comparisons: Quick Examples

- **Sorting by salary**
  ```java
  empStream.sorted((e1, e2) -> e1.getSalary() - e2.getSalary())
  ```

- **Richest Employee**
  ```java
  empStream.max((e1, e2) -> e1.getSalary() - e2.getSalary()).get()
  ```

- **Words with duplicates removed**
  ```java
  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**
  ```java
  public int firstNameComparer(Person other) {
    System.out.println("Comparing first names");
    return firstName.compareTo(other.getFirstName());
  }
  ```
### Sorting by Last Name: Example

**Code**

```java
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**

```java
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**

```java
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**

```java
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**

```java
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

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

```java
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.
**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 and max take no arguments, unlike the Stream versions that need a Comparator
  - Output as int[]
    - toArray()
  - Can make IntStream from int[], whereas Integer[] needed to make Stream<Integer>

- **Similar interfaces**
  - DoubleStream
  - LongStream

---

**Quick Examples**

- **Cost of fleet of cars**
  ```java
double totalCost =
  carList.stream().mapToDouble(Car::getPrice).sum();
```

- **Total population in region**
  ```java
  int population = countryList.stream()
    .filter(Utils::inRegion)
    .mapToInt(Country::getPopulation)
    .sum();
  ```

- **Average salary**
  ```java
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 OptionalInt
  - `sum()`: No arguments, output is int. Returns 0 for an empty IntStream.
  - `average`: No arguments, output is OptionalDouble
  - `toArray()`: No arguments, output is int[]
    - Although building an int[] from an IntStream is more convenient than building an Integer[] from a Stream<Integer>, turning an IntStream into a List<Integer> is hard, and you cannot simply do yourIntStream.collect(Collectors.toList()).

- **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 does not extend Stream (only BaseStream)
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[])
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

For additional materials, please see http://www.coreservlets.com/. The Java tutorial section contains complete source code for all examples in this tutorial series, plus exercises and exercise solutions for each topic.

## Reduction Operations

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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**
  
  ```java
  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);
  ```

- **Results**
  
  Concatenation of [a, b, c, d] is abcd.

**Concatenating Strings: Variations**

- **Data**
  
  ```java
  List<String> letters = Arrays.asList("a", "b", "c", "d");
  ```

- **Various reductions**
  
  - `letters.stream().reduce("", String::concat);`  
    -> "abcd"
  
    - 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);`  
    -> "DCBA"
  
    - Turns into uppercase as you go along
  
  - `letters.stream().reduce("", (s1,s2) -> s2+s1).toUpperCase();`  
    -> "DCBA"
  
    - Alternative to the above that turns into uppercase at the end after reduce is finished
Finding “Biggest” Employee

• Code

```java
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].

---

Finding Sum of Salaries: Two Alternatives

• Alternative 1
  – Use mapToInt, then use sum()

• Alternative 2
  – Use map, then use reduce
Finding Sum of Salaries

```java
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`
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);
}
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?

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