Java 8 Streams

"Code with Passion!"

Topics

- What is and Why Streams?
- Intermediate and terminal operations
- Laziness
- Parallelism

What is and Why Streams?

What is a Stream?

- Wrappers around data sources (examples of data sources are arrays or lists)
  - > Stream itself does not store data
  - > Stream carry values from a data source through a pipeline of operations
- Supports many convenient and high-performance operations expressed succinctly with Lambda expressions
  - > All Stream operations take Lambda expressions as arguments
- Operations can be executed in sequence or in parallel
  - > Parallel operation results in better performance when there are large number of items
- Support laziness
  - > Many Stream operations are postponed until how much data is eventually needed – this result in more efficient operations

Issues of using Collections for processing

- Issue #1: You have to use “for” loop or ”while” loop (external iteration) in order to get the answer you want - basically you have to specify “how it needs to be done” instead of “what needs to be done” letting the system to handle the iteration (internal iteration)
  - Example #1: You have a list of customers. You want to find out who spent the most during the month of May among these customers
  - Example #2: You also want to compute the average age of these customers
- Issue #2: Writing parallelizable code with collection is very hard
  - Example: The number of customers could be in the range of millions. And processing each of these customers in sequential manner could be very slow

Java 8 Streams to the Rescue!

- Stream lets you process data in a declarative way - simpler code
  - You specify "what needs to be done" not "how it needs to done"
  - More English-like description of a problem to solve (expressive)

- Streams support parallel processing (concurrency)
  - Streams can leverage multi-core architectures without you having to write a single line of multi-threaded code
  - Streams is easier to optimize due to "functional purity" (there is no global state to be maintained)

Example #1: Using Collection in Java 7

- Suppose you want to compute sum of all Integer's whose value is greater than 10, you would write code like following

```
private static int sumIterator(List<Integer> list) {
    Iterator<Integer> it = list.iterator();
    int sum = 0;
    while (it.hasNext()) {
        int num = it.next();
        if (num > 10) {
            sum += num;
        }
    }
    return sum;
}
```

You have to specify how it needs to be done using either for loop or while loop

Example #1: Using Stream in Java 8

- Same logic can be rewritten using Stream - simpler, fluent, parallel

```
// Non-parallel stream code
private static int sumStream(List<Integer> list) {
    return list.stream()              // convert the List to  sequential stream
               .filter(i -> i > 10)   // filter only the number > 10
               .mapToInt(i -> i)      // generate Integer stream
               .sum();                 // perform sum operation
}

// Parallel stream code
private static int sumStream(List<Integer> list) {
    return list.parallelStream()      // convert the List to  parallel stream
               .filter(i -> i > 10)
               .mapToInt(i -> i)
               .sum();
}
```

Example #2: Using Collection in Java 7

- You want to (1) find all transactions of type Grocery and (2) return a list of transaction IDs (3) sorted in decreasing order of transaction value

```
List<Transaction> groceryTransactions = new ArrayList<>();
for (Transaction t : allTransactions) {
    if (t.getType() == TransactionType.GROCERY) {
        groceryTransactions.add(t);
    }
}
Collections.sort(groceryTransactions, new Comparator<Transaction>() {
    public int compare(Transaction t1, Transaction t2) {
        return t2.getValue()
                .compareTo(t1.getValue());
    }
});
List<Integer> transactionIds = new ArrayList<>();
for (Transaction t : groceryTransactions) {
    transactionIds.add(t.getId());
}
```

Select Grocery transactions

Sort based on transaction value

Return list of transaction ids

Example #2: Using Stream in Java 8

- Same logic can be rewritten using Stream - simpler, fluent, parallel

```
// Non-parallel
List<Integer> transactionsIds =
    transactions.stream()
        .filter(t -> t.getType() == TransactionType.GROCERY)
        .sorted(Comparator.comparing(Transaction::getValue).reversed())
        .map(Transaction::getId)
        .collect(Collectors.toList());

// Parallel
List<Integer> transactionsIds =
    transactions.parallelStream()
        .filter(t -> t.getType() == TransactionType.GROCERY)
        .sorted(Comparator.comparing(Transaction::getValue).reversed())
        .map(Transaction::getId)
        .collect(Collectors.toList());
```

Collections vs Streams

- Collections are about data while streams are about computations
- Using the Collection interface requires iteration to be done by the developer (for example, using “for” or “while” loop)
  - This is called external iteration
- In contrast, the Streams library does the iteration for you and takes care of storing the resulting stream value somewhere; you merely provide a function saying what’s to be done
  - This is called internal iteration

Lab:

Exercise 1: External vs Internal Iteration
1621_javase8_streams.zip

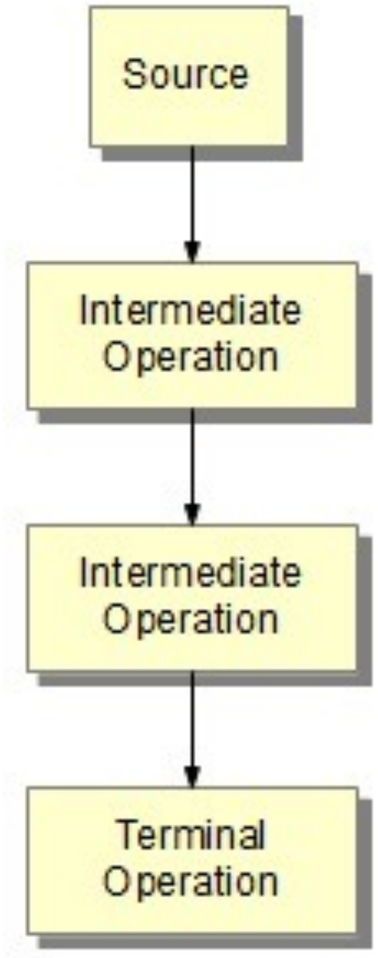
Intermediate and Terminal Operations

Stream Operations

- Stream-base processing is a pipe of operations
  - > Pipe is made of multiple intermediate operations
  - > And a single terminal operation at the end

- Intermediate operations
  - > *filter, map, sorted*

- Terminal operations
  - > *count, sum, reduce, forEach, findFirst, etc.*



Working with Stream involves

- Think of it as a pipeline that is made of
  - A data source (such as a collection object)
  - A chain of intermediate operations, which form a stream pipeline
  - One terminal operation, which
    - Represents end of pipeline and
    - Triggers execution of the stream pipeline and produces a result

Types of Stream Operations

- Filtering operations
  - *filter (Predicate)*
  - *distinct*
  - *limit(n)*
  - *skip(n)*
- Finding and matching operations
  - *anyMatch, allMatch, and noneMatch*
- Mapping operations
  - *map*
- Reducing operations
  - *reduce*

Intermediate Operations

- Stream producing
  - Always returns another stream
- Always lazy
  - Actual work is always triggered by a terminal operation
- Two types of intermediate operations
  - Stateless operations - don't require information of other items
  - Stateful operations - require information of other items
- Stateless operations
  - *filter, map, ..*
- Stateful operations
  - *distinct, sorted, limit, peek, ..*

Lab:

Exercise 2: Intermediate Operations
1621_javase8_streams.zip

Terminal Operations

- Represents end of pipeline
  - Produces a result from a pipeline - the result could a List, an Integer, or even void (any non-Stream type)
- Triggers intermediate operations (this is called Lazy)
  - Intermediate operations do not perform any processing until a terminal operation is invoked on the stream pipeline; they are “lazy.”
  - This is because intermediate operations can usually be “merged” and processed into a single pass, thus results in efficient processing

Terminal Operations

- *forEach*
- *count and sum*
- *findFirst, findAny*
- *anyMatch, allMatch, noneMatch*
- *reduce*

Terminal Operation: forEach

- Performs an action for each element of a stream
- The behavior of this operation is non-deterministic
  - For parallel stream pipelines, this operation does not guarantee to respect the encountering order of the stream, as doing so would sacrifice the benefit of parallelism

```
List<Integer> numbers = Arrays.asList(1, 2, 3, 4, 5, 6, 7, 8);

numbers.stream()
       .filter(p -> p > 5)
       .forEach(p -> System.out.println(p + " "));
```

Terminal Operation: count and sum

- *count*
  - Returns the count of elements in the stream
- *sum*
  - Returns the sum of values of elements in the stream

```
List<Integer> numbers = Arrays.asList(1, 2, 3, 4, 5, 6, 7, 8);

long count =  numbers.stream().filter(n -> n > 3).count();
int sum =  numbers.stream().filter(n -> n > 3).mapToInt(i->i).sum();
```

Terminal Operation: findFirst, findAny

- *findFirst*
  - Returns an Optional describing the first element of the stream, or an empty Optional if the stream is empty

  Optional<T> findFirst()
- *findAny*
  - Returns an Optional describing some element of the stream, or an empty Optional if the stream is empty

  Optional<T> findAny()
  - The behavior of this operation is explicitly non-deterministic; it is free to select any element in the stream

```
Optional<String> firstNameWithD = names4.filter(i -> i.startsWith("D")).findFirst();
if(firstNameWithD.isPresent()){
   System.out.println("First Name starting with D = "+ firstNameWithD.get());
}
```

Terminal Operation: anyMatch, allMatch, noneMatch

- anyMatch(Predicate predicate)
  - Returns whether any element of this stream matches the provided predicate
- allMatch(Predicate predicate)
  - Returns whether all elements of this stream match the provided predicate
- noneMatch(Predicate predicate)
  - Returns whether no elements of this stream match the provided predicate

```
List<Integer> numbers = Arrays.asList(1, 2, 3, 4, 6, 7, 8);

boolean result = numbers.stream().anyMatch(i -> i==5);  // false
result = numbers.stream().allMatch(i -> i<10);              // true
result = numbers.stream().noneMatch(i -> i==10);         // true
```

Terminal Operation: reduce

- Performs a reduction on the elements of the stream, using an associative accumulation function, and returns an Optional describing the reduced value, if any

```
List<Integer> numbers = Arrays.asList(1, 2, 3, 4, 5);

Optional<Integer> intOptional = numbers.stream().reduce((i,j) -> {return i*j;});
if (intOptional.isPresent()) {
    System.out.println("Multiplication through reduce = " + intOptional.get()); // 120
}
```

Lab:

Exercise 3: Terminal Operations
1621_javase8_streams.zip

Laziness

Laziness

- Intermediate operator runs only when terminate operator asks

```
// An example stream without a terminal operator
Stream.of("d2", "a2", "b1", "b3", "c")
        .map(s -> s.toUpperCase())
        .filter(s -> {System.out.println(s); return s.startsWith("B");}); // no print
```

Laziness Example

- In the example below, limit(2) uses short-circuiting; we need to process only part of the stream, not all of it, to return a result - similar to evaluating a large Boolean expression

```
List<Integer> numbers = Arrays.asList(1, 2, 3, 4, 5, 6, 7, 8);
List<Integer> twoEvenSquares =
    numbers.stream()
        .filter(n -> {
            System.out.println("filtering " + n);
            return n % 2 == 0;
        })
        .map(n -> {
            System.out.println("mapping " + n);
            return n * n;
        })
        .limit(2)
        .collect(Collectors.toList());
```

```
filtering 1
filtering 2
mapping 2
filtering 3
filtering 4
mapping 4
```

Observe that only two items are processed

Lab:

Exercise 4: Laziness
1621_javase8_streams.zip

Parallelism

Why Parallelism in Java 8 Streams?

- The join/fork framework introduced in Java 7 still requires developers to specify how the problems are subdivided (partitioned)
  - With aggregate operations in Java 8, it is the Java runtime that performs this partitioning and combining of solutions for you

- Collections are not thread-safe
  - Aggregate operations and parallel streams enable you to implement parallelism with non-thread-safe collections provided that you do not modify the collection while you are operating on it

Why Parallelism in Java 8 Streams?

- You can execute streams in serial or in parallel
  - When a stream executes in parallel, the Java runtime partitions the stream into multiple substreams
  - Aggregate operations iterate over and process these substreams in parallel and then combine the results
- To create a parallel stream
  - Invoke the operation Collection.parallelStream
  - Invoke the operation BaseStream.parallel

```
double average = roster
    .parallelStream()
    .filter(p -> p.getGender() == Person.Sex.MALE)
    .mapToInt(Person::getAge)
    .average()
    .getAsDouble();
```

Lab:

Exercise 5: Parallel stream
1621_javase8_streams.zip

Code with Passion!