CS 213 – Software Methodology

Spring 2017

Lecture 25: Apr 25

Streams (Java 8)

Example: Movie Stats

```
public class Movie {

    public static enum Genre {
       ACTION, ADVENTURE, DRAMA, MYSTERY, ROMANCE, SCIFI, THRILLER
    }

    private String name;
    private int year;
    private int rating;
    private Genre category;

    public Movie(String name, int year, int rating, Genre genre) {
       this.name=name; this.year=year; this.rating=rating; category=genre;
    }

    public String getName() { return name; }

    public int getYear() { return year; }

    public int getRating() { return rating; }

    public Genre getCategory() { return category; }

}
```

Example: Movie Stats

```
public static List<Movie> movies = Arrays.asList(
    new Movie("Mad Max: Fury Road”,2015,
              5,Genre.ACTION),
    new Movie("Straight Outta Compton”, 2015,
              5,Genre.DRAMA),
    new Movie("Fifty Shades of Grey”, 2015,
              1,Genre.DRAMA),
    new Movie("American Sniper, 2014,
              4,Genre.ACTION),
    new Movie("Transcendence”, 2014,
              1,Genre.THRILLER),
    new Movie("Conan The Barbarian”, 2011,
              2,Genre.ADVENTURE),
    new Movie("The Last Airbender”, 2010,
              2,Genre.ADVENTURE),
    new Movie("Harry Potter and the Deathly Hallows: Part 1”, 2010,
              4,Genre.ADVENTURE),
    new Movie("Sicario”, 2015,
              4,Genre.MYSTERY),
    new Movie("The Gift”, 2000,
              3,Genre.MYSTERY)
    );
```

Movies: Ratings < 3

Want to list names of movies with rating < 3

Iterator Version:

Implement a filter + mapper that will filter Movie instances on some predicate, and map these instances to the associated movie names

```
public static <T,R>
List<R> filterMap(List<T> list, Predicate<T> p, Function<T,R> f) {
    List<R> result = new ArrayList<R>();
    for (T t: list) {
       if (p.test(t)) {
          result.add(f.apply(t));
       }
    }
    return result;
}
```

Call the filter+mapper:

```
System.out.println(
   filterMap(movies, m -> m.getRating() < 3, Movie::getName)
);
```

Movies: Ratings < 3

Want to list names of movies with rating < 3

Stream Version:

Source the movies list to a stream and apply a sequence of stream operations:

```
List<String> badMovies =
     movies.stream()
            .filter(m -> m.getRating() < 3)
            .map(Movie::getName)
            .collect(toList());
System.out.println(badMovies);
```

Returns an instance of interface type `java.util.stream.Stream`

```
[Fifty Shades of Grey, Transcendence, Conan The Barbarian, The Last Airbender]
```

Benefits of Streams

Declarative:

You specify what you want to get done, don't worry about how

Composable:

You can put together a chain of operations to express a complex processing pipeline while keeping the code and intention clear

Parallelizable:

Streams can be run in parallel with a trivial change:

```
List<String> badMovies =
    movies.parallelStream()
          .filter(...)
          ...
```

The mechanics of scheduling to multiple cores is handled by VM/OS

Stream Operation Types

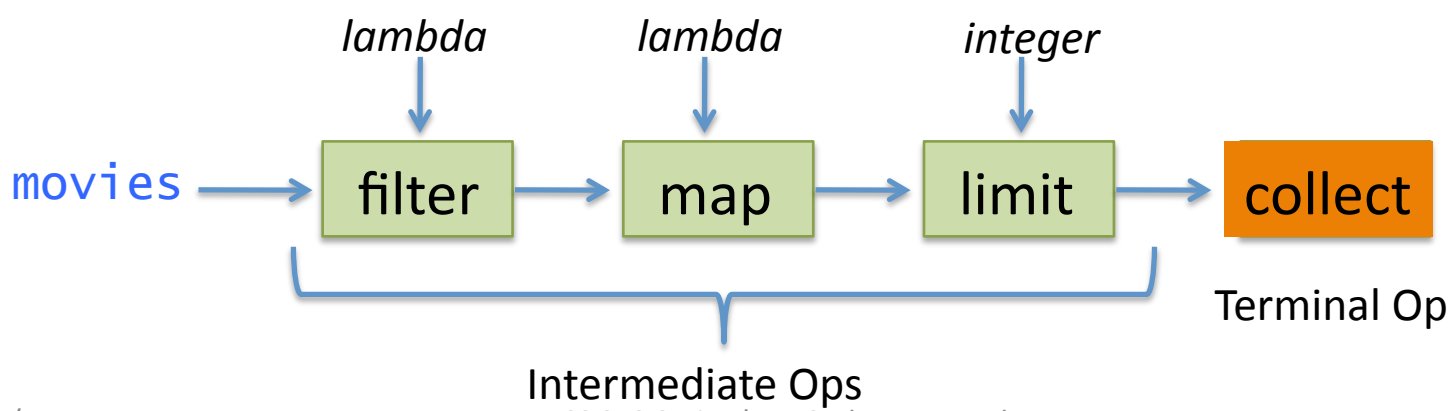
Streams operations are either intermediate or terminal

An intermediate operation results in a stream

A terminal operation produces a non-stream result

```
List<String> badMovies =
    movies.stream()
          .filter(m -> m.getRating() < 3)
          .map(Movie::getName)
          .limit(2)
          .collect(toList());
```

```
[Fifty Shades of Grey, Transcendence]
```



Breaking it Down, With Full Typing of all Intermediate Structures

```
Stream<Movie> movieStream = movies.stream();

movieStream = movieStream.filter(m -> m.getRating() < 3);

Stream<String> movieNameStream = movieStream.map(Movie::getName);

List<String> movieNameList = movieNameStream.collect(toList());
```

Short-Circuiting of Operations

```
List<String> names =
movies.stream()
  .filter(m -> {
                System.out.println("filtering " + m.getName());
                return m.getRating() < 3;
              })
  .map(m -> {
             System.out.println("mapping " + m.getName());
             return m.getName();
           })
  .limit(2)
  .collect(toList());
System.out.println(names);
```

```
filtering Mad Max: Fury Road
filtering Straight Outta Compton
filtering Fifty Shades of Grey
mapping Fifty Shades of Grey
filtering American Sniper
filtering Transcendence
mapping Transcendence
[Fifty Shades of Grey, Transcendence]
```

NOT every item in the list is processed.
As soon as the limit is reached,
processing stops (short-circuiting).
Also, filtering and mapping do not
happen in strict sequence—they are interleaved.
Bottom line: Operations are executed in an optimal sequence,
which may be different from the programmed sequence.

Terminal Operations

Terminal operations can return a primitive, an object, or void

```
int adventureMoviesCount = (int)
movies.stream()
  .filter(m -> m.getCategory() == Genre.ADVENTURE)
  .count(); // returns a long int
```

```
3
```

```
// forEach operation consumes the stream
movies.stream()
      .filter(m -> m.getCategory() == Genre.ACTION)

      .sorted(comparing(Movie::getName).reversed())

      .map(Movie::getName)

      .forEach(System.out::println);
```

```
Max Max: Fury Road
American Sniper
```

Static method
`java.util.Comparator.comparing`

Returns a `Comparator` that reverses the comparison order of `Comparator` on which it is applied

Sources for Streams (Aside from Collection.stream)

1. Values

Static method
`java.util.stream.Stream.of`

```
Stream<String> gimme =
   Stream.of("Spotlight","Mad Max","Martian",
             "Revenant","Big Short","The Danish Girl");

gimme.map(String::toUpperCase)
     .forEach(System.out::println);
```

```
SPOTLIGHT
MAD MAX
MARTIAN
REVENANT
BIG SHORT
THE DANISH GIRL
```

Sources for Streams

2. Array

```
int[] primes = {2,3,5,7,11,13,19,23,29};

IntStream primeStream = Arrays.stream(primes);

System.out.println(primeStream.sum());
```

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interface
`java.util.stream.IntStream`
for streams that hold primitive int values

Static method
`java.util.Arrays.stream`

"Reduction" method in
`java.util.stream.IntStream`

Sources for Streams

3. Numerical range

Static method
`java.util.stream.IntStream.rangeClosed`

```
1
4     IntStream
9     .rangeClosed(1,10)
16    .map(i -> i*i)
25    .forEach(System.out::println);
36
49
64
81
100
```

Returned type is `IntStream`, not `Stream<Integer>`

Static method `java.util.stream.IntStream.range(1,10)` gives a right-open range 1..9

Typed Streams

There are three typed streams: `IntStream`, `DoubleStream`, and `LongStream`, with slightly different sets of methods. (All of these hold values of the corresponding primitive type.)

`DoubleStream`, for instance, does not have a range method

Sources for Streams

4. File

Class (not interface) `java.nio.file.Files`

Class (not interface) `java.nio.file.Paths`

static

static

```
try {
   Stream<String> lines = Files.lines(Paths.get("file.txt"));
   lines
      .map(line -> line.split(" ").length)
      .forEach(System.out::println);

} catch (IOException e) {
   System.out.println(e.getMessage());
}
```

?

number of words in each line of file.txt

Class `java.nio.file.Files` consists exclusively of static methods that operate on files and directories

Class `java.nio.file.Paths` consists exclusively of (two) static methods that create file or URI path objects out of strings

Sources for Streams

5. Functions
   a. iterate

Static method
`java.util.stream.Stream.iterate`

```
Stream
    .iterate(1, n -> n+3)
    .limit(10)
    .forEach(System.out::println);
```

infinite sequence 1,4,7,10,… (`Stream<Integer>`)

`iterate` takes a seed parameter of type `T`, and a `UnaryOperator<T>` (which is a special kind of the `Function` interface that has same result type as input, i.e. `Function<T, T>`, and inherits the apply method from `Function`)

The function is applied on each successive value, resulting in the sequence:
`seed, f(seed), f(f(seed)) ...`

```
Stream
    .iterate("*", s -> s + "*")
    .limit(6)
    .forEach(System.out::println);
```

```
*
**
***
****
*****
******
```

Sources for Streams

5. Functions
   b. generate

Static method
`java.util.stream.Stream.generate`

```
Stream
.generate(Math::random)
.limit(5)
.forEach(System.out::println);
```

infinite sequence of random numbers
(`Stream<Double>`)

`generate` takes a `Supplier<T>` as parameter and generates an infinite sequence of type `T` elements

The typed streams `IntStream`, `DoubleStream`, and `LongStream`, also have generate methods, that return an instance of that typed stream:

```
// infinite stream of ones
IntStream ones = IntStream.generate(() -> 1);
```

Lambda for functional interface
`java.util.function.IntSupplier`

Useful Stream Operations

Some additional ops aside from the ones we have already seen

Identifying distinct occurrences

```
String[][] cars =
 {
     {"Honda","Civic","2017"},
     {"Toyota","Camry","2017"},
     {"Ford","Fusion","2017"},
     {"Subaru","Forrester","2017"},
     {"Honda","Accord","2017"},
     {"Ford","Focus","2017"},
     {"Honda","Pilot","2017"}
};
```

```
Arrays
  .stream(cars)

  .map(mm -> mm[0])

  .distinct()
  .forEach(System.out::println);
```

gives `Stream<String[]>`

mapping array to its first element

?

```
Honda
Toyota
Ford
Subaru
```

distinct car makes

Useful Stream Operations

Finding and Matching

1. Find any – version 1

E.g. find any 1-star rated movie in `movies` list

```
movies
  .stream()
  .filter(m -> m.getRating() == 1)
  .map(Movie::getName)
  .findAny()
  .ifPresent(System.out::println);
```

```
Fifty Shades of Grey
```

`findAny` returns a `java.util.Optional<T>` object

`Optional` is a container that may or may not contain a null value

The `ifPresent` method in `Optional` accepts a `Consumer` that is applied to the contained value, if any. If not, the method does nothing

Useful Stream Operations

Finding and Matching

1. Find any – version 2

E.g. find any 2014 movie in `movies` list that was 5-star rated

```
System.out.println(
  movies
    .stream()
    .filter(m -> m.getYear() == 2014 && m.getRating() == 5)
    .map(Movie::getName)
    .findAny()
    .orElse("No match"));
```

```
No match
```

The `orElse` method in `Optional` returns the contained value, if any. If not, it returns the supplied value

Short Circuiting

```
movies
  .stream()
  .filter(m -> {
                System.out.println("filtering" + m.getName());
                return m.getRating() == 1;
              })
  .map(m -> {
             System.out.println("mapping " + m.getName());
             return m.getName();
           })
  .findAny()
  .ifPresent(System.out::println);
```

```
filtering Max Max: Fury Road
filtering Straight Outta Compton
filtering Fifty Shades of Grey
mapping Fifty Shades of Grey
Fifty Shades of Grey
```

Stream processing is cut short as soon as there is an instance in the stream before `findAny`

Useful Stream Operations

Finding and Matching

2. Find first

E.g. find the first movie in `movies` list that got a 4-star rating

```
System.out.println(
movies
  .stream()
  .filter(m -> m.getRating() == 4)
  .map(Movie::getName)
  .findFirst()
  .orElse("No match"));
```

```
American Sniper
```

Useful Stream Operations

Finding and Matching

3. Predicate Matching

a. Is there any item that matches a predicate?

```
System.out.println(
  movies
    .stream()
    .anyMatch(m -> m.getCategory() == Genre.MYSTERY && m.getRating() > 3));
```

true

b. Do all items match a predicate?

```
System.out.println(
  Arrays
    .stream(cars)
    .map(mmy -> mmy[2])
    .allMatch(y -> y.equals("2016")));
```

? true

```
String[][] cars =
 {
     {"Honda","Civic","2016"},
     {"Toyota","Camry","2016"},
     {"Ford","Fusion","2016"},
     {"Subaru","Forrester","2016"},
     {"Honda","Accord","2016"},
     {"Ford","Focus","2016"},
     {"Honda","Pilot","2016"}
};
```

c. There's also a `noneMatch` method

Useful Stream Operations

Reduce

Sum

E.g. find the number of words in an input file

```
try {
   Stream<String> lines = Files.lines(Paths.get("file.txt"));
   lines
      .map(line -> line.split(" ").length)
      .reduce(Integer::sum)
      .ifPresent(System.out::println);
} catch (IOException e) {
   System.out.println(e.getMessage());
}
```

This version of `reduce` takes as parameter a `BinaryOperator<T>` instance, which serves as an associative accumulator. In this example, the associative accumulator is the `sum` method in the `Integer` class. The return type of this reduce is `Optional<T>`

Useful Stream Operations

Reduce

`Optional<T> reduce (BinaryOperator<T> accumulator)`

Here's how the previous `reduce` is actually implemented:

```
boolean foundAny = false;
T result = null;
for (T element: this stream) {
    if (!foundAny) {
       foundAny = true;
       result = element;
    } else {
       result = accumulator.apply(result, element);
    }
}
return foundAny ? Optional.of(result) : Optional.empty();
```

The accumulator function must be an associative function because the accumulation process is not guaranteed to work through the stream items sequentially

Useful Stream Operations

Reduce

Product – Using an identity element as seed

E.g. find the factorial of n

```
IntStream is = IntStream.rangeClosed(1,n);
int fact = is.reduce(1,(x,y) -> x*y);
```

identity

This version of reduce returns an instance of the identity type (`Integer`, in this case)

Sum method, numeric stream

```
try {
   Stream<String> lines = Files.lines(Paths.get("file.txt"));
   System.out.println(
    lines
      .mapToInt(line -> line.split(" ").length)
      .sum()
   );
} catch (IOException e) {
   System.out.println(e.getMessage());
}
```

Returns an `IntStream`

Can also do max and min reductions on `IntStream`

Useful Stream Operations

Reduce

E.g. find the average star rating of all movies in `movies` list

```
Optional<Integer> opt =
    movies.stream()
          .map(Movie::getRating)
          .reduce(Integer::sum);

try {
    System.out.println(opt.get()*1f/movies.stream().count());
} catch (NoSuchElementException e) {
    System.out.println("No movies in list");
}
```

The `Optional` class's `get` method returns the contained value, or throws a `NoSuchElementException` if none exists

Useful Stream Operations

Reduce – Averaging with IntStream

E.g. find the average star rating of all movies in `movies` list

```
OptionalDouble optDbl =
    movies.stream()
          .mapToInt(Movie::getRating)
          .average();

System.out.println(optDbl.orElse(0));
```

← `mapToInt` returns `IntStream`