

Java 8 Workshop

Lambda Expressions and the Stream API

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What's new in Java 8?

- Lambda Expressions
- Stream API
- The `Optional` data type
- Security Enhancements
- JavaFX Improvements
- New and Improved Tools
- ... and much more!

Prerequisites

- Java 8 JDK installed
- Some IDE, I will be using IntelliJ Idea Community Edition
 - Make sure the IDE sees your Java 8 JDK so it can compile the code
- Familiarity with Java
- Your best attitude 😊

Setup and Goals

- Download <https://github.com/jdifebo/java8> and import into IDE
- Configure libraries for unit tests
 - Open file EmployeeManagerTest.java
 - Add JUnit4 to classpath by hovering over one of the compilation errors
 - Choose “Run Tests”
 - All tests should fail
- Implement methods using lambda expressions and Stream API
 - Each method can be implemented in a single line by chaining Stream operations!
- Take a look at the provided classes

What are Lambda Expressions?

- A lambda expression is an anonymous function that is typically passed as a parameter to other functions.
- While Lambda Expressions are new to Java, they have been around for decades in other languages.

Javascript

```
function(x){return x * 2}
```

Javascript (ES6)

```
x => x * 2
```

Ruby

```
{ |x| x * 2 }
```

Java 8

```
x -> x * 2
```

Lambda Expressions in Java 8

- Several existing interfaces have been modified to allow using Lambda Expressions
 - Now marked with `@FunctionalInterface` annotation
 - Functional interfaces have exactly one abstract method
 - Examples include `Comparator`, `Runnable`, `ActionListener`
- New interfaces created specifically for lambda expressions and streams

Sorting a List of Employees

- Goal: Write a method that takes `List<Employee> employees` and sorts the list based on the `name` attribute
- No return value, just sort the input list

Without Java 8

```
public static void sortEmployeesByName(List<Employee> employees) {  
    employees.sort(new Comparator<Employee>() {  
        @Override  
        public int compare(Employee e1, Employee e2) {  
            return e1.getName().compareTo(e2.getName());  
        }  
    });  
}
```

Sorting a List of Employees

- Goal: Write a method that takes `List<Employee> employees` and sorts the list based on the `name` attribute
- No return value, just sort the input list

With Java 8

```
public static void sortEmployeesByName(List<Employee> employees) {  
    employees.sort((e1, e2) -> e1.getName().compareTo(e2.getName()));  
}
```

- We can actually do slightly better, we'll revisit the `Comparator` class later

Lambda Expression Details

`(e1, e2) -> e1.getName().compareTo(e2.getName())`

- `(e1, e2)` are the parameters, both of type `Employee`
 - We can pick whatever names we want, I could choose `(x, y)` if I wanted to
 - Type Inference is used to figure out the type that these should be, so we don't need to specify that they are of type `Employee`
 - Still strongly typed, will throw compile-time errors for mistakes
- `e1.getName().compareTo(e2.getName())` is the method body
 - No return statement needed for one-line methods

Example: Lambda Expressions

- Goal: Implement the sortEmployeesByName method in EmployeeManager.java
- First unit test should pass!

With Java 8

```
public static void sortEmployeesByName(List<Employee> employees) {  
    employees.sort((e1, e2) -> e1.getName().compareTo(e2.getName()));  
}
```

Method References

- Provides easy-to-read lambda expressions for methods that already have a name
- Can be used anywhere that a lambda expression can be used
- Refer to a static method using `ClassName::methodName`
- Refer to an object's methods with `objectName::methodName`

Sorting a List of Employees

- Goal: Use a method reference to sort a list of employees

With Java 8 Method References

```
public class LambdaExpressionExample {
    /* other methods up here*/

    public void sortEmployeesByName(List<Employee> employees) {
        employees.sort(LambdaExpressionExample::compareEmployeesByName);
    }

    private static int compareEmployeesByName(Employee e1, Employee e2) {
        return e1.getName().compareTo(e2.getName());
    }
}
```

What is the Stream API?

[A stream is a] sequence of elements supporting sequential and parallel aggregate operations.

- Stream JavaDoc

- A stream is not a data structure, similar to iterators
- A "sequence of elements" can include
 - Collections (`List` and `Set`)
 - Objects from a database
 - Lines from a file (via `BufferedReader`)
 - Arbitrary mathematical sequences like the Fibonacci sequence
 - Can be infinite!

Stream API: anyMatch()

- Returns `true` if any element in the stream matches the given condition
- Input is a function that has one parameter and returns a boolean
 - We can use a lambda expression!

Stream API: anyMatch()

- Goal: Write a method that takes a `String` `name` and returns `true` if any employee in the list has that name

Without Java 8

```
public boolean containsName(String name) {  
    for (Employee employee : employees) {  
        if (employee.getName().equals(name)) {  
            return true;  
        }  
    }  
    return false;  
}
```

Example: anyMatch()

- Goal: Write a method that takes a `String` `name` and returns `true` if any employee in the list has that name

With Java 8

```
public boolean containsName(String name) {  
    return employees.stream()  
        .anyMatch(employee -> employee.getName().equals(name));  
}
```

- Exercise: Implement this one too!

Stream API: `allMatch()` and `noneMatch()`

- Methods work exactly the same as `anyMatch()`
- `allMatch()` returns true if all elements in the stream satisfy the given function
- `noneMatch()` returns true if no elements in the stream satisfy the given function

Stream API: allMatch()

- Goal: Write a method that takes an `int salary` and returns `true` if all employees have salaries greater than that value

Without Java 8

```
public boolean areAllSalariesGreaterThan(int salary){
    for (Employee employee : employees){
        if (!(employee.getSalary() > salary)){
            return false;
        }
    }
    return true;
}
```

Exercise: allMatch()

- Goal: Write a method that takes an `int salary` and returns `true` if all employees have salaries greater than that value

Without Java 8

```
public boolean areAllSalariesGreaterThan(int salary) {  
    return employees.stream().allMatch( ? ? ? ? ? );  
}
```

Solution: allMatch()

- Goal: Write a method that takes an `int salary` and returns `true` if all employees have salaries greater than that value

Without Java 8

```
public boolean areAllSalariesGreaterThan(int salary){  
    return employees.stream()  
        .allMatch(employee -> employee.getSalary() > salary);  
}
```

Aside: The Optional Class

- Class `Optional<T>` defined in `java.util`
- Useful when a method might not return a value
- Better than returning `null` since it informs the user that they must check if the value is present
- Contains methods like `isPresent()`, `get()`, and `orElse()`

Optional: Sample Usage

- Suppose that `getName()` returns `Optional<String>`

Sample Usage

```
Optional<String> name = getName();  
if (name.isPresent()) {  
    System.out.println(name.get());  
}  
else {  
    System.out.println("No name was found!");  
}
```

Optional: Sample Usage

- Suppose that `getName()` returns `Optional<String>`

Provide a default value

```
Optional<String> name = getName();  
System.out.println(name.orElse("No name was found!"));
```

Throw an exception

```
Optional<String> name = getName();  
System.out.println(name.orElseThrow(() -> new Exception()));
```

Throw an exception with a method reference

```
Optional<String> name = getName();  
System.out.println(name.orElseThrow(Exception::new));
```

Stream API: max()

- Returns an `Optional` containing the maximum element of a stream
 - Will return an empty `Optional` if the stream is empty
- Takes 1 parameter, a `Comparator` function
- There is also a `min()` function
- Goal: Write a method that finds the employee with the highest salary in a list and return an `Optional<Employee>` of that employee
 - Return an empty `Optional` if the list is empty

Stream API: max()

Without Streams

```
public Optional<Employee> findHighestSalary() {  
    if (employees.size() == 0 ) {  
        return Optional.empty();  
    }  
    else {  
        Employee highestEmployee = employees.get(0);  
        for (Employee employee : employees) {  
            if (employee.getSalary() > highestEmployee.getSalary()) {  
                highestEmployee = employee;  
            }  
        }  
        return Optional.of(highestEmployee);  
    }  
}
```

Exercise: max()

- Goal: Write a method that finds the employee with the highest salary in a list and return an `Optional<Employee>` of that employee
 - Return an empty `Optional` if the list is empty

Without Streams

```
public Optional<Employee> findHighestSalary() {  
    return employees.stream().max( ? ? ? ? ? );  
}
```

- Reminder: `max()` takes a `comparator<Employee>`, a function that takes 2 employees as parameters and returns either a negative number, 0, or a positive number to denote order

Solution: max()

- Goal: Write a method that finds the employee with the highest salary in a list and return an `Optional<Employee>` of that employee
 - Return an empty `Optional` if the list is empty

Without Streams

```
public Optional<Employee> findHighestSalary() {  
    return employees.stream()  
        .max((e1, e2) -> Integer.compare(e1.getSalary(), e2.getSalary()));  
}
```

More Optionals

- Suppose that `getEmployee()` returns `Optional<Employee>`

Sample Usage

```
Optional<Employee> employee = getEmployee();  
if (employee.isPresent()) {  
    System.out.println(employee.get().getName());  
}  
else {  
    System.out.println("No employee was found!");  
}
```


What just happened?

- `employee.map()` returns a new `Optional` of a different type
 - `emp -> emp.getName()` means the new `Optional` will be of type `String` since `emp.getName()` returns a `String`
- Now that we have an `Optional<String>` again, we can use `.orElse("No employee was found!")` to provide a default `String` value
- `ifPresent` always returns a `boolean`, `map` will allow you to access a potentially empty object

Exercise: Optionals

- Goal: Write a method that finds the name of the employee with the highest salary
 - Return “*No employees were found!*” if the list is empty

Without Streams

```
public String findNameOfHighestSalary() {  
    return employees.stream()  
        .max((e1, e2) -> Integer.compare(e1.getSalary(), e2.getSalary()))  
        . ? ? ? ?  
        . ? ? ? ?;  
}
```

Solution: Optionals

- `map()` because we don't care about the entire employee, only the employee's name
- `orElse()` to provide a default value

Without Streams

```
public String findNameOfHighestSalary () {  
    return employees.stream()  
        .max((e1, e2) -> Integer.compare(e1.getSalary(), e2.getSalary()))  
        .map(emp -> emp.getName())  
        .orElse("No employees were found!");  
}
```


Terminal vs Intermediate Operations

- Terminal operations return a useful value
 - `anyMatch()` returns a `boolean`
 - `max()` returns an `Optional`
- Intermediate operations return a new stream as a result
 - Does not modify the source of the stream (the underlying list for example)
 - Can be chained together into a pipeline to perform several operations
 - Use lazy evaluation; no work will be done until a terminal operation is called
 - Examples include `filter()`, `map()`, `sorted()`, `limit()`, `distinct()`

Stream API: `map()` and `collect()`

- `map()` creates a new stream by applying a function to each element of an existing stream
 - Related to the `map()` method that `Optionals` have, but not the same
- `collect()` "combines" elements of a stream in some way
 - Usually used for putting elements into a new collection
 - Convenience classes can be used via the `Collectors` class
 - i.e. `.collect(Collectors.toList())`
 - Alternatively can specify your own functions for more precise behavior
 - This is a terminal operation since it returns a useful object and not a stream

Stream API: map() and collect()

- Goal: Write a method that returns a `List<String>` of the employees' names

Without Java 8

```
public List<String> findEmployeeNames() {  
    List<String> names = new ArrayList<String>(employees.size());  
    for (Employee employee : employees) {  
        names.add(employee.getName());  
    }  
    return names;  
}
```

Example: map() and collect()

- Goal: Write a method that returns a `List<String>` of the employees' names

With Java 8

```
public List<String> findEmployeeNames() {  
    return employees.stream()  
        .map(emp -> emp.getName())  
        .collect(Collectors.toList());  
}
```

With Java 8 and Method References

```
public List<String> findEmployeeNames() {  
    return employees.stream()  
        .map(Employee::getName)  
        .collect(Collectors.toList());  
}
```

Stream API: filter() and count()

- `filter()` creates a new stream by removing some elements from the original stream
 - Takes a function that returns a boolean, just like `anyMatch()`
- `count()` simply returns the number of elements in the stream
 - Returns a `long`, just in case the stream is huge!

Stream API: filter() and count()

- Goal: Write a method takes a `String office` and returns the number of employees at that office

Without Java 8

```
public long countEmployeesAtOffice(String office) {  
    long count = 0;  
    for (Employee employee : employees){  
        if (employee.getOffice().equals(office)){  
            count++;  
        }  
    }  
    return count;  
}
```

Example: filter() and count()

- Goal: Write a method that takes `String office` and returns the number of employees whose office is equal to the provided office

With Java 8

```
public long countEmployeesAtOffice(String office) {  
    return employees.stream()  
        .filter(employee -> employee.getOffice().equals(office))  
        .count();  
}
```

Exercise: Combine map, collect, and filter

- Goal: Write a method takes a `String office` and returns a `List<String>` of the names of employees at that office

With Java 8

```
public List<String> findEmployeeNamesAtOffice(String office) {  
    return employees.stream()  
        .filter(e -> e.getOffice().equals(office))  
        .map(e -> e.getName())  
        .collect(toList());  
}
```


Stream API: `distinct()`

- `distinct()` creates a new stream by removing duplicate elements from the original stream
 - Takes no parameters
 - Uses `.equals()` to check for equality

Exercise: distinct()

- Goal: Write a method that returns the number of different offices there are among the employees
 - Hint: You need other stream methods too!

With Java 8

```
public long countNumberOfOffices() {
```

Exercise: distinct()

- Goal: Write a method that returns the number of different offices there are among the employees
 - Hint: You need other stream methods too!

With Java 8

```
public long countNumberOfOffices() {  
    return employees.stream()  
        .map(Employee::getOffice)  
        .distinct()  
        .count();  
}
```

Exercise: A New Way to Collect

- Goal: Write a method that returns a `String` that is a comma-separated list of all of the different offices
 - Hint: use `Collectors.joining(CharSequence delimiter)`

With Java 8

```
public Set<String> findDistinctOffices() {  
  
  
  
  
  
  
}
```

Solution: A New Way to Collect

- Goal: Write a method that returns a `String` that is a comma-separated list of all of the different offices
 - Hint: use `Collectors.joining(CharSequence delimiter)`

With Java 8

```
public Set<String> findDistinctOffices() {  
    return employees.stream()  
        .map(Employee::getOffice)  
        .distinct()  
        .collect(Collectors.joining(", "));  
}
```

Stream API: `findFirst()` and `findAny()`

- `findFirst()` returns an `Optional` containing the first element in the stream
 - Returns an empty `Optional` if the stream has no elements
- `findAny()` returns an `Optional` containing an element in the stream
 - Not guaranteed to be the first element
 - Might be faster when processing streams in parallel
- Usually want to perform a `filter()` first

Exercise: findAny()

- **Goal: Write a method that takes a `String office` and returns an `Optional<Employee>` of any employee at that office**
 - Return an empty `Optional` if no employee is found

With Java 8

```
public Optional<Employee> findAnyEmployeeAtOffice(String office) {  
  
  
  
  
  
  
}
```

Exercise: findAny()

- **Goal:** Write a method that takes a `String office` and returns an `Optional<Employee>` of any employee at that office
 - Return an empty `Optional` if no employee is found

With Java 8

```
public Optional<Employee> findAnyEmployeeAtOffice(String office){  
    return employees.stream()  
        .filter(employee -> employee.getOffice().equals(office))  
        .findAny();  
}
```


Stream API: `sorted()` and `limit()`

- `sorted()` creates a new stream by sorting the original stream
 - One version takes no parameters, uses natural ordering
 - Second version takes a `Comparator` just like `max()`
- `limit()` truncates the stream to be no longer than a given size
 - Takes a `long` as a parameter
 - If the stream isn't that long, the entire stream is returned

Example: sorted() and limit()

- Goal: Write a method that returns the 10 highest paid employees in Ann Arbor

With Java 8

```
public List<Employee> topSalaryAtOffice(String office, int limit) {  
    return employees.stream()  
        .filter(emp -> emp.getOffice().equals("Ann Arbor"))  
        .sorted((e1, e2) -> Integer.compare(e2.getSalary(), e1.getSalary()))  
        .limit(10)  
        .collect(Collectors.toList());  
}
```

Revisiting Comparators

- Comparator class has some static methods to easily make comparators

To sort employees by the name field

Replace this	<code>(e1, e2) -> e1.getName().compareTo(e2.getName())</code>
With this	<code>Comparator.comparing(employee -> employee.getName())</code>
Or better	<code>Comparator.comparing(Employee::getName)</code>

To sort employees by salary in decending order

```
Comparator.comparingInt(Employee::getSalary).reversed()
```

- `comparingInt`, `comparingLong`, `comparingDouble` useful for primitive types to avoid unnecessary boxing and unboxing
- `reversed()` takes a comparator and returns a comparator in the opposite order

Revisiting Comparators

- <https://docs.oracle.com/javase/8/docs/api/java/util/Comparator.html>
- Is a functional interface
 - Has only one method that needs to be implemented
 - Compatible with lambda expressions and method references to implement the single method
- Has default methods such as `reversed()`
 - Interface with implemented methods???
 - Required to expand behavior of existing classes without breaking existing implementations

Stream API: mapToInt()

- `mapToInt()` returns an `IntStream`, a special type of stream to deal with `int` primitives
 - Takes a function that maps to an `int`, e.g. `emp -> emp.getSalary()`
 - Has `average()` and `sum()` convenience methods that don't work on arbitrary objects
- `mapToDouble()` and `mapToLong()` also exist for those primitives

Example: mapToInt()

- Goal: Write a method that returns the average employee salary
 - Return 0 if the list is empty

With Java 8

```
public double findAverageSalary() {  
    return employees.stream()  
        .mapToInt(Employee::getSalary)  
        .average() // this returns an OptionalDouble!  
        .orElse(0);  
}
```

Exercise: mapToInt()

- Goal: Write a method that returns the total salary of all employees at an office

With Java 8

```
public int findTotalSalaryOfOffice(String office) {  
  
  
  
  
  
}
```

Solution: mapToInt()

- Goal: Write a method that returns the total salary of all employees at an office

With Java 8

```
public int findTotalSalaryOfOffice(String office) {  
    return employees.stream()  
        .filter(employee -> employee.getOffice().equals(office))  
        .mapToInt(Employee::getSalary)  
        .sum();  
}
```


Important Notes and Fun Facts

- To preserve correct behavior, two rules must be followed
 1. Streams must be non-interfering (they do not modify the stream source)
 2. Must be stateless (results should not depend on any state that might change during execution)
- Streams cannot be reused after a terminal operation is invoked
 - Remember, no work is done until a terminal operation is used
- In some cases, streams can be infinite
 - Many methods will never return for infinite streams

Recap of Stream Methods

- Intermediate Operations

- `map()`
- `filter()`
- `distinct()`
- `sorted()`
- `limit()`
- `mapToInt()`,
`mapToDouble()`,
`mapToLong()`

- Terminal Operations

- `anyMatch()`, `allMatch()`,
`noneMatch()`
- `max()`, `min()`
- `collect()`
- `count()`
- `findAny()`

Other Important Methods

- `reduce()`
 - Extremely flexible, can be used to implement several terminal operations
 - Rarely needed in practice
- `collect()` (the other method signature)
 - Useful for loading data into arbitrary data structures
 - Most use cases are already covered by the `Collectors` class

Other Important Methods

- `toArray()`
 - Replacement for `.collect(Collectors.toList())`
 - Excellent if legacy code expects an array and not a list, use it if you need to
- `forEach()`
 - Also extremely flexible, lets the programmer execute arbitrary code for each element in a stream
 - Very easy to violate stream contract and potentially get unexpected behavior
 - Can just write a for loop instead

Parallel Processing

- Many streams implement the `.parallel()` method
- Automatically enables parallel processing of the stream
 - Work is divided between multiple threads
 - After threads complete, end result is then merged together
- Can actually be less efficient for small streams with simple operations
 - Millions of elements is still "small".
- Can potentially be much faster for very large streams or when the operations involved are time consuming

Parallel Processing

- As with all parallel processing, side-effects must be carefully accounted for
 - Two threads modifying the same variable at the same time will cause errors
- Side-effects are highly discouraged even for sequential streams

Parallel Processing Gone Wrong

- What is the output of the following code?

100000, 47270, 46942, 65382, or 40942?

Bad Parallel Processing

```
static int n = 0;
public static void main(String[] args) {
    IntStream.range(0, 100000).parallel().forEach(i -> n++);
    System.out.println(n);
}
```

Summary

- Streams can perform useful operations on collections
- Intermediate operations return new streams based on modifying the elements of the previous stream
- Terminal operations return useful values
- Stream operations can take lambda expressions to shorten code
- Many streams support parallel execution
 - Must be extra careful to ensure correct behavior

Thank You!

Questions?