Lecture 9

Functional-style Data Processing

Introduction to Streams

SOEN 6441, Summer 2018

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Outline

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From Collections to Streams

Given a list of `Dish` objects, return the names of dishes low in calories, sorted by calories

```
// Step 1: Filter
List<Dish> lowCaloricDishes = new ArrayList<>();
for(Dish d: menu){
  if(d.getCalories() < 400){
    lowCaloricDishes.add(d);
  }
}

// Step 2: Sort
Collections.sort(lowCaloricDishes, new Comparator<Dish>() {
  public int compare(Dish d1, Dish d2){
    return Integer.compare(d1.getCalories(), d2.getCalories());
  }
});

// Step 3: Process
List<String> lowCaloricDishesName = new ArrayList<>();
for(Dish d: lowCaloricDishes){
  lowCaloricDishesName.add(d.getName());
}
```

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With Java 8 Streams

```
List<String> lowCaloricDishesName =
    menu.stream()
        .filter(d -> d.getCalories() < 400)
        .sorted(comparing(Dish::getCalories))
        .map(Dish::getName)
        .collect(toList());
```

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Multicore architecture: Run in parallel

```
List<String> lowCaloricDishesName =
    menu.parallelStream()
        .filter(d -> d.getCalories() < 400)
        .sorted(comparing(Dish::getCalories))
        .map(Dish::getName)
        .collect(toList());
```

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Stream Pipelines

Chaining stream operations forming a stream pipeline

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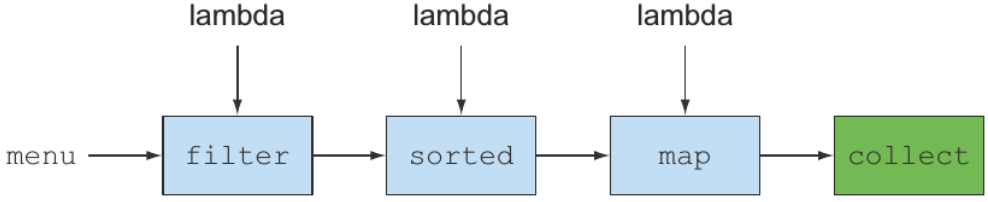

Stream Processing Example

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Group dishes by type into a `Map`

```
Map<Dish.Type, List<Dish>> dishesByType =
    menu.stream().collect(groupingBy(Dish::getType));
```

Output Example

```
{FISH=[prawns, salmon],
 OTHER=[french fries, rice, season fruit, pizza],
 MEAT=[pork, beef, chicken]}
```

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New Streams API (`java.util.stream.Stream`)

With Java 8 you can write code that is

Declarative: More concise and readable

Composable: Greater flexibility

Parallelizable: Better performance

Outline

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Example Class: Dish

```
public class Dish {
  private final String name;
  private final boolean vegetarian;
  private final int calories;
  private final Type type;

  public Dish(String name, boolean vegetarian, int calories, Type type) {
    this.name = name;
    this.vegetarian = vegetarian;
    this.calories = calories;
    this.type = type;
  }

  public String getName() { return name; }
  public boolean isVegetarian() { return vegetarian; }
  public int getCalories() { return calories; }
  public Type getType() { return type; }

  @Override
  public String toString() {
    return name;
  }

  public enum Type { MEAT, FISH, OTHER }
}
```

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Example Data: Menu items

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```
List<Dish> menu = Arrays.asList(
  new Dish("pork", false, 800, Dish.Type.MEAT),
  new Dish("beef", false, 700, Dish.Type.MEAT),
  new Dish("chicken", false, 400, Dish.Type.MEAT),
  new Dish("french␣fries", true, 530, Dish.Type.OTHER),
  new Dish("rice", true, 350, Dish.Type.OTHER),
  new Dish("season␣fruit", true, 120, Dish.Type.OTHER),
  new Dish("pizza", true, 550, Dish.Type.OTHER),
  new Dish("prawns", false, 300, Dish.Type.FISH),
  new Dish("salmon", false, 450, Dish.Type.FISH) );
```

Stream Definition

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Stream

A stream is a sequence of elements from a source that supports data processing operations.

Stream Characteristics

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Details

Sequence of elements: A stream provides an interface to a sequenced set of values of a specific element type. Unlike collections, they focus on expressing computations (e.g., `filter`, `sorted`, `map`).
Collections are about data; streams are about computations.

Source: Streams consume from a data-providing source such as collections, arrays, or I/O resources. Generating a stream from an ordered collection preserves the ordering.

Data processing operations: Streams support database-like operations and common operations from functional programming languages to manipulate data, such as `filter`, `map`, `reduce`, `find`, `match`, `sort`, and so on. Stream operations can be executed either sequentially or in parallel.

Pipelining: Many stream operations return a stream themselves, allowing operations to be chained and form a larger pipeline. This enables certain optimizations, such as laziness and short-circuiting.

Internal iteration: In contrast to collections, which are iterated explicitly using an iterator, stream operations do the iteration behind the scenes for you.

Stream Example

Filtering a menu using a stream to find out three high-calorie dish names

```
import static java.util.stream.Collectors.toList;

List<String> threeHighCaloricDishNames =
  menu.stream()
      .filter(d -> d.getCalories() > 300)
      .map(Dish::getName)
      .limit(3)
      .collect(toList());

System.out.println(threeHighCaloricDishNames);
```

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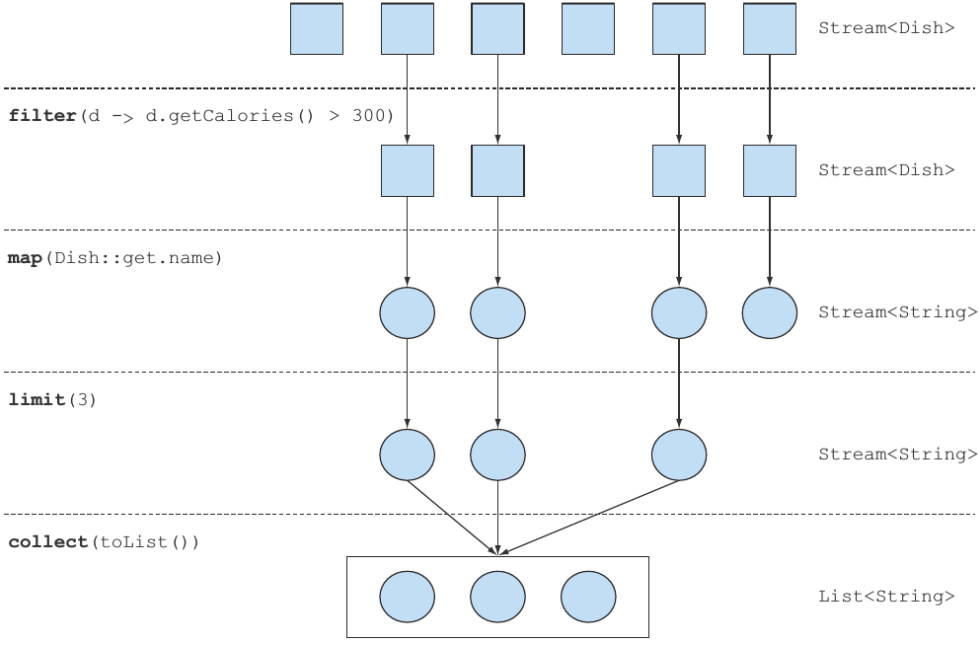
Menu stream



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Stream operations in the example

`filter` takes a lambda to exclude certain elements from the stream

```
d -> d.getCalories() > 300
```

`map` takes a lambda to transform an element into another one or to extract information

```
d -> d.getName()
```

`limit` truncates a stream to a given number of elements

```
limit(3)
```

`collect` converts a stream into another form (e.g., a `List`)

```
toList()
```

Streams vs. collections

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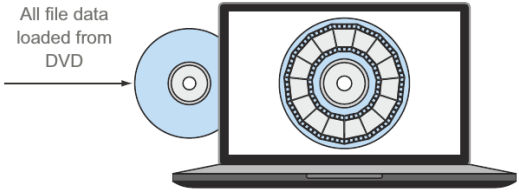
A collection in Java 8 is like a movie stored on DVD

Eager construction means waiting for computation of ALL values

All file data loaded from DVD

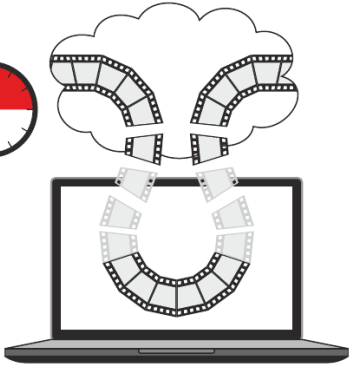


Like a DVD, a collection holds all the values that the data structure currently has—every element in the collection has to be computed before it can be added to the collection.

A stream in Java 8 is like a movie streamed over the internet.

Lazy construction means values are computed only as needed.

Internet



Like a streaming video, values are computed as they are needed.

Streams vs. collections

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Some differences

Collections:

- Can add or remove elements
- Contents eagerly constructed before processing
- E.g., *"make a list of all even numbers"* before processing will not work
- A set of values spread out in space (computer memory) – all exist at the same time

Streams:

- Conceptually fixed data structure (you can't add or remove elements)
- Elements are lazily constructed – only *as* and *when* required (computed on demand)
- Can process a *stream of even numbers* – next number will only be computed when needed
- Compare with, e.g., Internet search (showing next 10 search results) or "infinite scrolling" on web pages
- A set of values spread out in time – not all of them have to exist in the same space (computer memory)

Stream Traversal

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A stream can be traversed only once

```
List<String> title = Arrays.asList("Java8", "In", "Action");
Stream<String> s = title.stream();
s.forEach(System.out::println);
```

OK!

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

```
java.lang.IllegalStateException:
stream has already been operated upon or closed.
```

Collection Iterators: External Iteration

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Iterating with `for-each` loop

```
List<String> names = new ArrayList<>();
for(Dish d: menu){
  names.add(d.getName());
}
```

Translated by compiler into `Iterator` object

```
List<String> names = new ArrayList<>();
Iterator<String> iterator = menu.iterator();
while(iterator.hasNext()) {
  Dish d = iterator.next();
  names.add(d.getName());
}
```

Syntactic Sugar

The `for-each` construct is an example of so-called syntactic sugar

Stream Iterators

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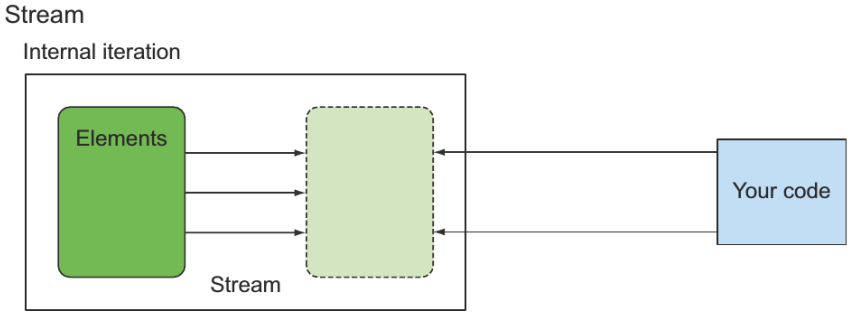
Streams use *internal* iteration

```
List<String> names = menu.stream()
                          .map(Dish::getName)
                          .collect(toList());
```

Internal vs. external iteration



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Outline

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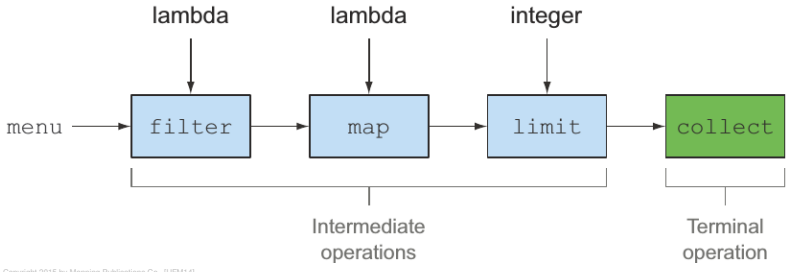
Stream Operation Categories

Stream Pipeline Example

```
List<String> names = menu.stream()
                          .filter(d -> d.getCalories() > 300)
                          .map(Dish::getName)
                          .limit(3)
                          .collect(toList());
```



Two groups of operations: Intermediate & Terminal

- `filter`, `map`, `limit` etc. can be connected to form a pipeline
- `collect` causes the pipeline to be executed and closes it

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Intermediate operations

Understanding lazy execution

```
List<String> names =
  menu.stream()
      .filter(d -> {
        System.out.println("filtering" + d.getName());
        return d.getCalories() > 300; })
      .map(d -> {
        System.out.println("mapping" + d.getName());
        return d.getName(); })
      .limit(3)
      .collect(toList());

System.out.println(names);
```

Output

```
filtering pork
mapping pork
filtering beef
mapping beef
filtering chicken
mapping chicken
[pork, beef, chicken]
```

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Terminal operations

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Definition

Terminal operations produce a result from a stream pipeline. A result is any nonstream value, e.g., `List`, `Integer`, `void`.

Example

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

Identify the operations

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What are the *intermediate* and *terminal* operations in this pipeline?

```
long count = menu.stream()
                 .filter(d -> d.getCalories() > 300)
                 .distinct()
                 .limit(3)
                 .count();
```

Working with streams

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In general, you need three items

- A data source (such as a collection) to perform a query on
- A chain of intermediate operations that form a stream pipeline
- A terminal operation that executes the stream pipeline and produces a result

Similar idea to the Builder design pattern.

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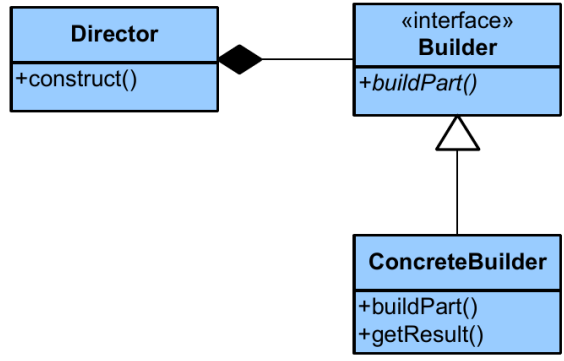
Builder

Type: Creational

What it is:
Separate the construction of a complex object from its representing so that the same construction process can create different representations.



Intermediate and Terminal Stream Operations (excerpt)

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Operation	Type	Return type	Argument of the operation	Function descriptor
`filter`	Intermediate	`Stream<T>`	`Predicate<T>`	`T -> boolean`
`map`	Intermediate	`Stream<R>`	`Function<T, R>`	`T -> R`
`limit`	Intermediate	`Stream<T>`		
`sorted`	Intermediate	`Stream<T>`	`Comparator<T>`	`(T, T) -> int`
`distinct`	Intermediate	`Stream<T>`		

Operation	Type	Purpose
`forEach`	Terminal	Consumes each element from a stream and applies a lambda to each of them. The operation returns `void`.
`count`	Terminal	Returns the number of elements in a stream. The operation returns a `long`.
`collect`	Terminal	Reduces the stream to create a collection such as a `List`, a `Map`, or even an `Integer`. See chapter 6 for more detail.

Summary

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Streams

- A stream is a sequence of elements from a source that supports data processing operations.
- Streams make use of internal iteration: the iteration is abstracted away through operations such as `filter`, `map`, and `sorted`.
- There are two types of stream operations: intermediate and terminal operations.
- Intermediate operations (e.g., `filter`, `map`) return a stream and can be chained together. They're used to set up a pipeline of operations but don't produce any result.
- Terminal operations such as `forEach` and `count` return a nonstream value and process a stream pipeline to return a result.
- The elements of a stream are computed on demand.

Outline

Reading Material

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Required

- [UFM14, Chapter 4] (Introducing Streams)

Supplemental

- [GHJV95] (Builder Design Pattern)

References

[GHJV95] E. Gamma, R. Helm, R. Johnson, and J. Vlissides.
Design Patterns: Elements of Reusable Object-Oriented Software.
Addison-Wesley, 1995.

[UFM14] Raoul-Gabriel Urma, Mario Fusco, and Alan Mycroft.
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