Multicore Programming
Reactive Programming

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Description

Reactive programming is programming with asynchronous data streams:

- Asynchronous like CompleteableFuture.
- Data streams like Stream.
Outline

General Concepts

Reactive Streams

Main Libraries

Summary and References
Outline

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Summary and References
Relation with Existing API

<table>
<thead>
<tr>
<th></th>
<th>single item</th>
<th>multiple items</th>
</tr>
</thead>
<tbody>
<tr>
<td>synchronous</td>
<td><code>T</code> data</td>
<td><code>Stream&lt;T&gt;</code> stream</td>
</tr>
<tr>
<td>asynchronous</td>
<td><code>CompletableFuture&lt;T&gt;</code> fut</td>
<td><code>Publisher&lt;T&gt;</code> pub</td>
</tr>
</tbody>
</table>

- A future/promise is to a value as publishers are to iterables/collections.
- Reacting to the completion of multiple futures (asynchronously, without blocking operation).
This is a click event represented by some value, e.g., a string.

This indicates the stream has completed.

This is an error.
Publish/Subscribe Model
Overflow Problem

- Too much pressure with push-based methods.
- Reactive programming is thus “pull-based” to control the pressure.
Backpressure

Asynchronous stream processing with non-blocking *backpressure*:

```
Publisher → Request N data items ← Subscriber
Push stream of N data items
```
Other Characteristics

**Composable** chaining operations (like stream and completable future).

**Lazy evaluation** evaluated as late as possible (like stream).

**Asynchronous** non-blocking operations (like completable future).

**Reusable/Cacheable** results can be reused (like completable future).

**Push-based** the data source initiates the processing (pull-based for stream).

**Message passing** data producers exchange messages containing the data (no shared-memory mechanism).
History and Technological Context

- Kind of dataflow programming
- Also called FRP (Functional Reactive Programming): functional, no side effect, immutable state, pure function.
- Related to observer and iterator design patterns.
- Close to actor concurrency model.
Relation with Reactive Systems

- Reactive programming can be used to build a reactive system.
- The Reactive Manifesto states the features that must be offered by a reactive system: responsive, resilient, elastic, message-driven.
The system responds in a timely manner if at all possible. Responsiveness is the cornerstone of **usability**.

The system stays responsive in the face of **failure**.

The system stays responsive under **varying workload**. It can react to changes in the input rate by increasing or decreasing the resources allocated to service these inputs.

The system relies on **asynchronous message passing** to establish a boundary between components that ensures loose coupling, isolation, and location transparency.
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General Concepts

Reactive Streams
  Flow API (Java 9)
    SubmissionPublisher
    Implementation Example

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Main Interfaces

```java
interface Publisher<T> {
    void subscribe(Subscriber<T> subscriber);
}

interface Subscriber<T> {
    void onSubscribe(Subscription subscription);
    void onNext(T item);
    void onError(Throwable throwable);
    void onComplete();
}

interface Subscription {
    void request(long n);
    void cancel();
}
```
Reactive Streams Specification
Simplified Communication Flow

Subscriber -> Publisher -> Subscription

subscribe()

new()
onSubscribe(Subscription)

loop [until completed]
request(int)

alt [no error]
onNext(T)

alt [error]
onError(Throwable)

alt [cancel subscription]
cancel()

onComplete()

Subscriber -> Publisher -> Subscription
## Dual to Iterable

<table>
<thead>
<tr>
<th>Event</th>
<th>Iterable (pull)</th>
<th>Observable (push)</th>
</tr>
</thead>
<tbody>
<tr>
<td>retrieve data</td>
<td><code>T next()</code></td>
<td><code>onNext(T)</code></td>
</tr>
<tr>
<td>discover error</td>
<td><code>throws Exception</code></td>
<td><code>onError(Exception)</code></td>
</tr>
<tr>
<td>complete</td>
<td><code>!hasNext()</code></td>
<td><code>onCompleted()</code></td>
</tr>
</tbody>
</table>
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Interface

Implementation of Flow.Publisher:

```java
SubmissionPublisher();
SubmissionPublisher(Executor executor,
       int maxBufferCapacity);
CompletableFuture<Void> consume(Consumer<T> cons);
int submit(T item);
void close();
```
Example

```java
var pub = new SubmissionPublisher<Integer>();
pub.consume(System.out::println);
pub.submit(1);
```
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Subscriber Example

class CustomSub implements Subscriber<Integer> {
    private Subscription subscription;
    public void onSubscribe(Subscription subscription) {
        this.subscription = subscription;
        subscription.request(1); }
    public void onNext(Integer value) {
        System.out.println(value);
        subscription.request(1); }
    public void onError(Throwable t) {
        System.err.println(t.getMessage()); }
    public void onComplete() {
        System.out.println("Done!"); }
}
Chaining SubmissionPublisher

```java
var pub1 = new SubmissionPublisher<Integer>();
var pub2 = new SubmissionPublisher<Integer>();
var pub3 = new SubmissionPublisher<Double>();
var pub4 = new SubmissionPublisher<Double>();
pub1.consume(x -> {
    pub2.submit(x * x);
});
pub1.consume(x -> {
    pub3.submit(x / 2.);
});
pub2.consume(x -> {
    System.out.println("Square is: " + x);
});
pub3.consume(x -> {
    if (x > 2) pub4.submit(x);
});
pub4.consume(x -> {
    System.out.println("Half (> 2) is: " + x);
});
pub1.submit(3);
pub1.submit(5);
```
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- **RxJava**: Reactive Extensions, Netflix (more than 50 different operations)
- **Reactor**: from Spring (equivalent to RxJava)
- **Akka**: actor model
RxJava Example

```java
Flowable<Integer> flow = Flowable.range(1, 5)
    .map(v -> v * v)
    .filter(v -> v % 3 == 0)
    .subscribe(System.out::println);
```

- Flowable implements Publisher.
- subscribe triggers the execution (as with terminal operations, lazy evaluation).
Marble Diagrams
Classic Operations

- `map`:

- `allMatch`:

- `true`:

- `skip(1)`:

- `reduce`:

- `exists`:

- `false`:

- `true`:

- `limit(2)`:
Advanced Operations
Concurrent Source

- By default, the main thread performs all operations (blocking).
- The operation `subscribeOn` specifies how data processing can be processed concurrently.
- The operation at each stage can be performed asynchronously on a specific executor.
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Official Documentation

- Documentation of class Flow
- Documentation of class SubmissionPublisher
- Documentation of class Flowable
- Documentation of class Flux
To Go Further

- https://akarnokd.blogspot.com/
- https://github.com/reactive-streams/reactive-streams-jvm
- Reactive Extensions (Rx) for Java or JavaScript:
  - http://reactivex.io/
  - https://github.com/ReactiveX/RxJava
  - http://introtorx.com/
  - https://gist.github.com/staltz/868e7e9bc2a7b8c1f754
- Reactor:
  - https://github.com/reactor/reactor-core
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