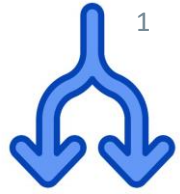
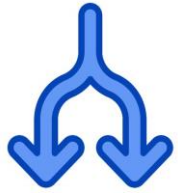


Practical Concurrent and Parallel Programming IX
RxJava

Jørgen Staunstrup

Motivations for Concurrency

From Week01

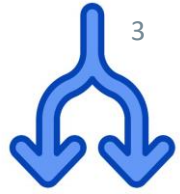


Inherent: User interfaces and other kinds of input/output

Exploitation: Hardware capable of simultaneously executing multiple streams of statements

Hidden: Enabling several programs to share some resources in a manner where each can act as if they had sole ownership

Agenda



- Motivation (Inherent concurrency)
- **User interfaces in Java (Android, Swing**, ...)
- Reactive programming (RxJava)

I/O in Java

```
St(a)rt, St(o)p or (R)eset:
```

```
Scanner myObj= new Scanner(System.in);
System.out.println(" St(a)rt, St(o)p or (R)eset: ");
String name= myObj.nextLine();  // Read user input
```

File: **`week09/code-lecture/SimpleRead.java`**

Problem: This will wait (and do nothing else) for user input

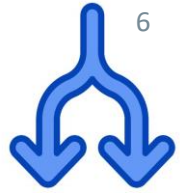
I/O in Java

```
St(a)rt, St(o)p or (R)eset:
```

```
public class Button extends Thread {
  public void run() {
  Scanner myObj= new Scanner(System.in);
  System.out.println(" St(a)rt, St(o)p or (R)eset: ");
  String name= myObj.nextLine();  // Read user input
    ...
}

new Button().start();
//The main thread continues ...
```

File: **week09/code-lecture/SimpleTRead.java**

Android (Java)



```
Button.setOnClickListener(
   v -> // ... Code handling button
);
```

This implicitly creates a thread


```
startButton.setOnClickListener( ... );

stopButton.setOnClickListener( ... );

resetButton.setOnClickListener( ... );
```

UI elements in Java

Not part of Java => external library

For the exercises we will use Java Swing

```
JButton startButton

startButton.addActionListener(e -> ...));
```

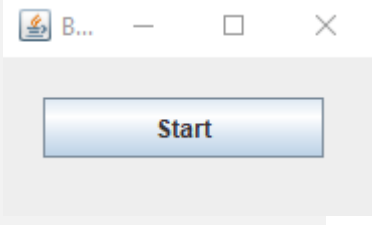
https://docs.oracle.com/javase/tutorial/uiswing/index.html

Swing example

For the exercises we will use Java Swing

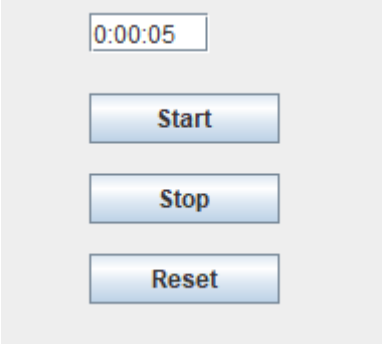
https://docs.oracle.com/javase/tutorial/uiswing/index.html

```
import java.awt.event.*;
import javax.swing.*;

class swingButton {
  public static void main(String[] args) { new swingButton(); }
  final private static JFrame f= new JFrame("Button Demo");
  final private JButton startButton= new JButton("Start");

  public swingButton(){
    f.setBounds(0, 0, 200, 120);
    f.setLayout(null);
    f.setVisible(true);
    startButton.setBounds(20, 20, 140, 30);
    startButton.addActionListener(new ActionListener(){
      public void actionPerformed(ActionEvent e){
        System.out.println("Start pushed");
      }
    });
    // set up user interface
    f.add(startButton);
  }
}
```



File: **week09/code-lecture/app…/swingButton.java**

Example: the Stopwatch

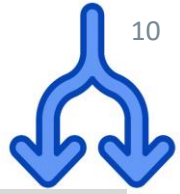


All three buttons must respond to clicking
When started the display must update every second

$\Rightarrow$ 4 streams
- one for each button
- one for handling the clock ticking

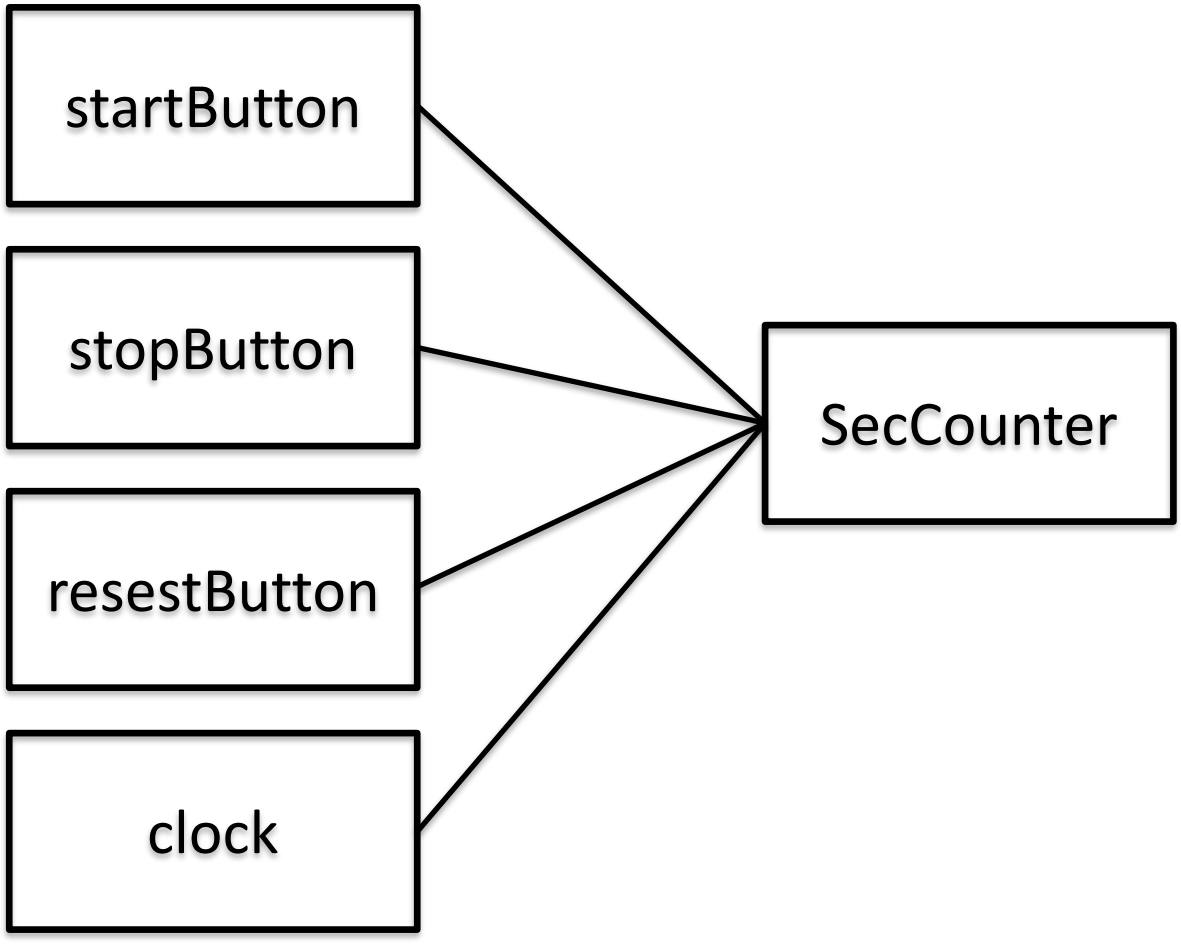
User interfaces and other kinds of input/output (*Inherent concurrency*)

Stopwatch (pseudocode)

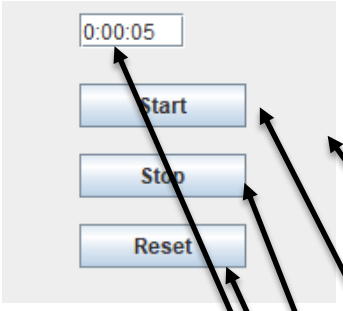


```
stream startButton= new stream(() -> {
  await(startButton); SecCounter.setRunning(true);
});

stream stopButton= new stream(() -> {
  await(startButton); SecCounter.setRunning(false);
});

stream resetButton= new stream(() -> {
  await(startButton); SecCounter.reset();
});

stream clock = new stream(() -> {
  sleep(1 second); write(SecCounter.incr());
});
```

Stopwatch



Swing example: Stopwatch

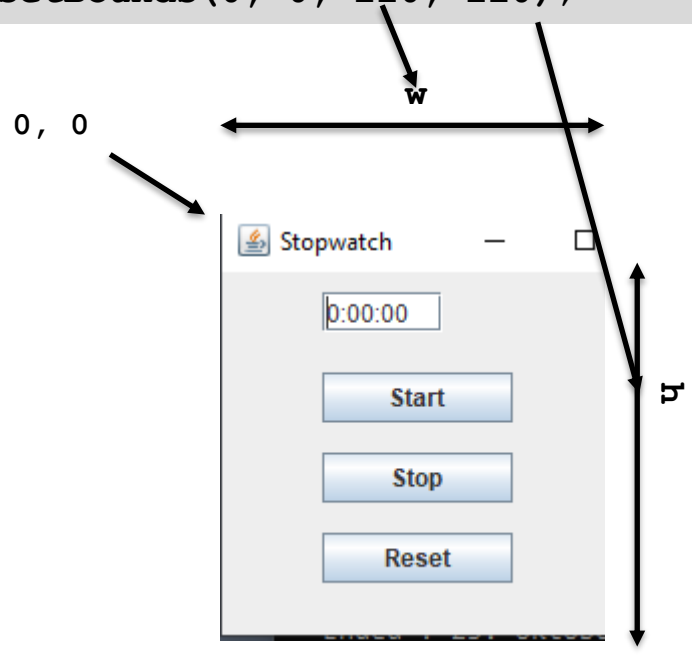



```
private static JFrame lf;

final private JButton startButton= new JButton("Start");
final private JButton stopButton= new JButton("Stop");
final private JButton resetButton= new JButton("Reset");

final private JTextField tf= new JTextField();
```

No need to learn Swing details for PCPP exercises !!!!

Swing canvas

```
final JFrame f= new JFrame("Stopwatch");
f.setBounds(0, 0, 220, 220);
```

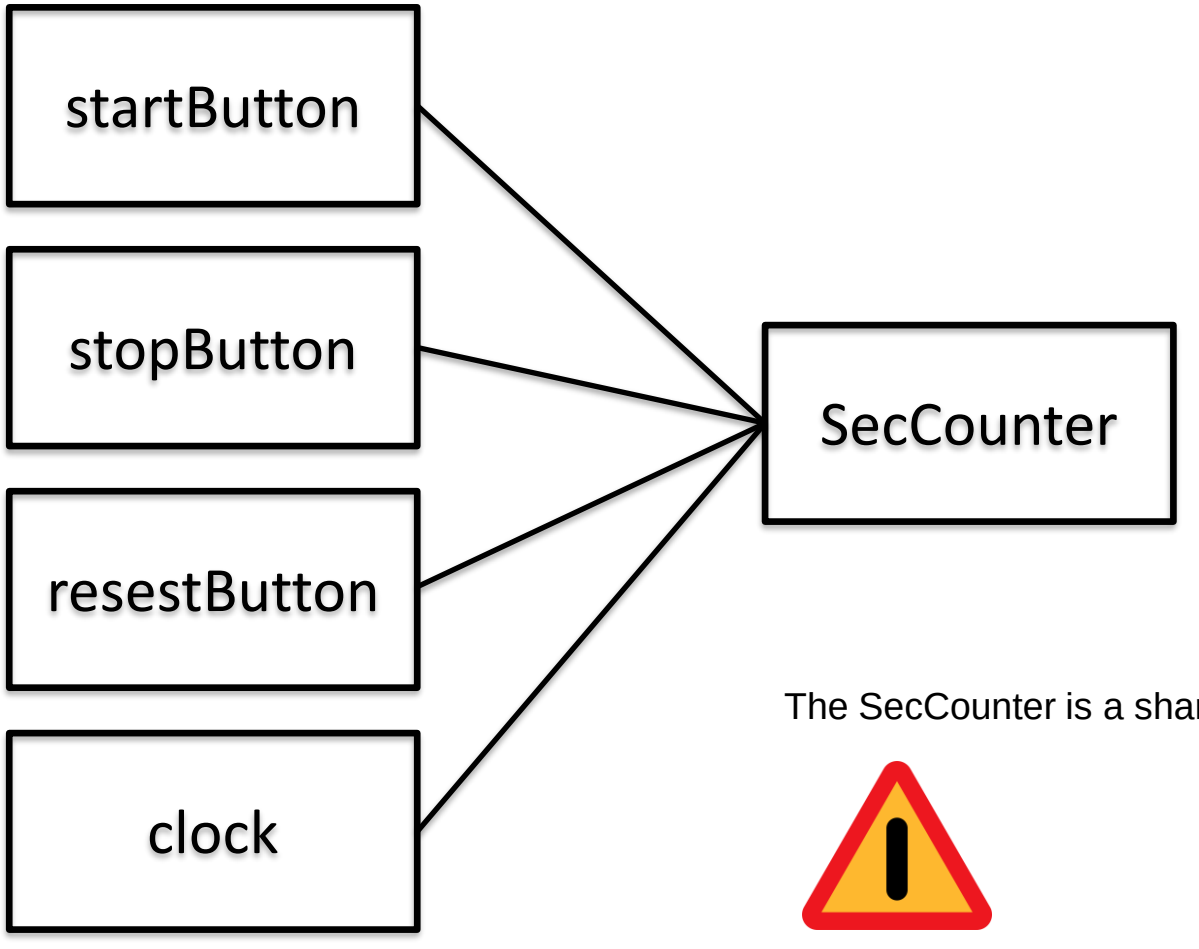



```
startButton.setBounds(50, 50, 95, 25);

stopButton.setBounds(50, 90, 95, 25);

resetButton.setBounds(50, 130, 95, 25);
```

```
public void setBounds(int x, int y, int width, int height)
```

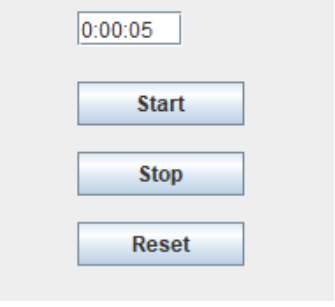
The unit of x, y, width and height is pixels

Stopwatch



The SecCounter is a shared object

startButton




```
JButton startButton= new JButton("Start");
JTextField tf= new JTextField();
..
startButton.addActionListener(new ActionListener(){
  public void actionPerformed(ActionEvent e){
     lC.setRunning(true);
  }
});
...
tf.setText(time);
```

"runnable"

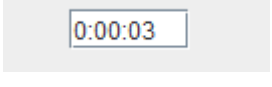
Stopwatch: clock

```
// Background Thread simulating a clock ticking every 1 seconde
new Thread() {
  private int seconds= 0;

  @Override
  public void run() {
    try {
      while ( true ) {
        TimeUnit.SECONDS.sleep(1);
        myUI.updateTime();
      }
    } catch (java.lang.InterruptedException e) {System.out.println(e.toString());}
  }
}.start();
```

Complete code in: **`code-exercises/…/Stopwatch.java`**

SecCounter

```
public class SecCounter {
private int seconds= -1;
  private boolean running= false;
  ...
  public SecCounter(int s, boolean r, JTextField tf){  ...  }

  public synchronized void reset() {
    running= false;
    seconds= 0;
    ...
  }
  public synchronized void setRunning(boolean running) { this.running= running; }

  public synchronized int incr(){  ...  }
}
```



= seconds

???

Stopwatch

Complete code in:

```
Week09/code-exercises/...

Stopwatch.java
SecCounter.java
stopWatchUI.java
```

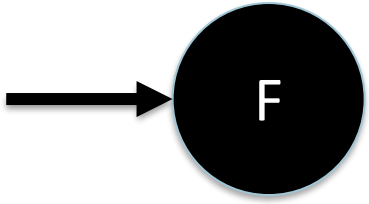
and

```
Week09/code-lecture/...

Stopwatch.java
SecCounter.java
stopWatchUI.java
```

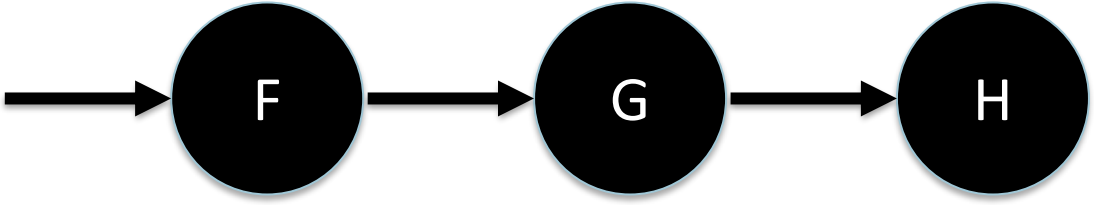
Agenda

- Motivation (Inherent concurrency)
- User interfaces in Java (Android, Swing, ...)
- **Reactive programming (RxJava)**

Reactive programming (RxJava)

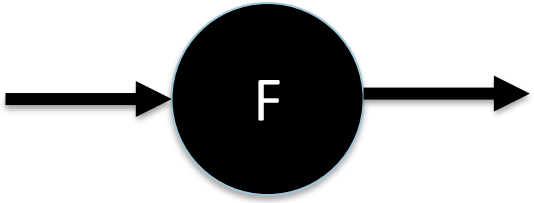


Compute a function F whenever
a new input is provided



Similarity with Java streams, but some important differences
(more in a few minutes)

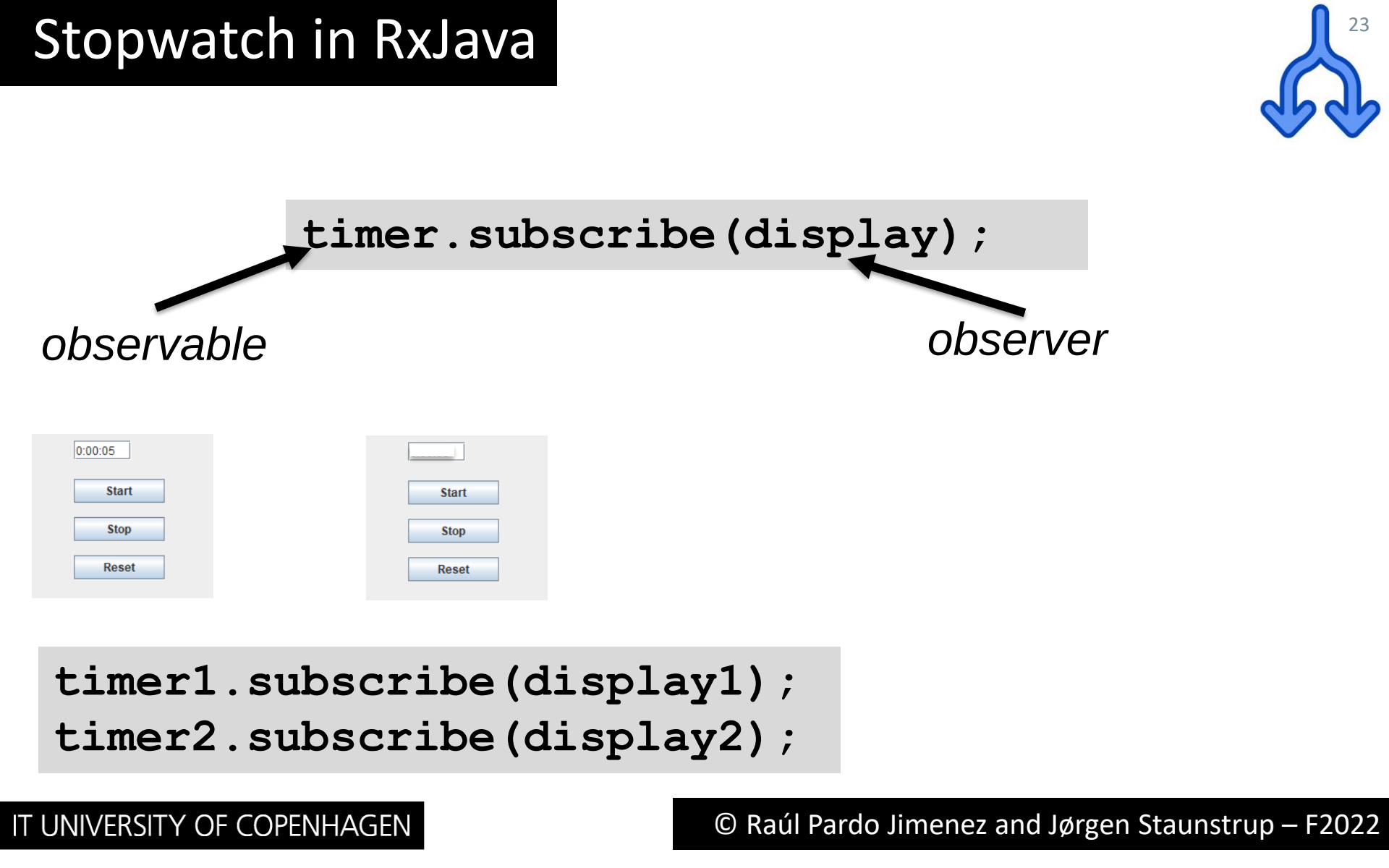
Observer/Observable




```
public class Data extends Observable {


... this.setChanged(); notifyObservers();


}
```

```
public class Compute implements Observer {

  public void update(Observable observable,
                     Object data) {
     ...
  }

}
```

Stopwatch in RxJava



```
timer.subscribe(display);
```

observable

observer


```
timer1.subscribe(display1);
timer2.subscribe(display2);
```

RxJava Observer

```
Observer<T> o= new Observer<T>() {

  @Override
  public void onSubscribe(Disposable d) {  }

  @Override
  public void onNext(<T> value) {
     ... // consume value
  }
  ...
}
```

RxJava Observable

```
Observable<T> ov
 = Observable.create(new ObservableOnSubscribe<T>() {
     @Override
     public void subscribe(ObservableEmitter<T> e){
       ...
       e.onNext( );

     }
   }
```

More on other kinds of Observables later

Rx practicalities

To use RxJava (in your exercises) import (at least):

```
import io.reactivex.Observable;
import io.reactivex.ObservableEmitter;
import io.reactivex.ObservableOnSubscribe;
import io.reactivex.Observer;
import io.reactivex.disposables.Disposable;
```

Your `build.gradle` must contain

```
 implementation
'io.reactivex.rxjava2:rxjava:2.2.21'
```

See example: **`code-exercises/app/build.gradle`**

RxJava code for the Stopwatch (part 1)

The clock emitting ticks is an observable

```
Observable<Integer> timer
  = Observable.create(new ObservableOnSubscribe<Integer>() {
      @Override
      public void subscribe(ObservableEmitter<Integer> e) throws Exception {
        new Thread() {
          @Override
          public void run() {
            try {
              while ( true ) {
                TimeUnit.SECONDS.sleep(1);
                e.onNext(1);
              }
            } catch (java.lang.InterruptedException e) { }
          }
        }.start();
      }
  });
```

RxJava code for the Stopwatch (part 2)

The buttons are also Observables

```
Observable<Integer> rxPush
    = Observable.create(new ObservableOnSubscribe<Integer>() {
      @Override
      public void subscribe(ObservableEmitter<Integer> e) throws Exception {
        nameButton.addActionListener(new ActionListener(){
          public void actionPerformed(ActionEvent ee){
            e.onNext(1);
          }
        });
      }
    });
```

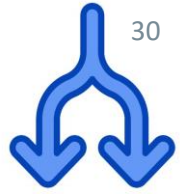
Complete code in: **`code-exercises/… /rxButton.java`**

RxJava code for the Stopwatch (part 3)

The display is an Observer

```
Observer<Integer> display= new Observer<Integer>() {
  @Override
  public void onNext(Integer value) {
    tf.setText(time);  // tf id the swing object for the text field
  }
};
```

Different types of Observables (1)



A Java stream can be made into an Rx observable

```
public static Stream<String> readWords(String filename) {
    ...   // from week 05
  }
```

Different types of Observables (1)

A Java stream can be made into an Rx observable

```
public static Stream<String> readWords(String filename) {
    ...   // from week 05
  }
```

```
public static Observable<String> readWords
 = Observable.create(new ObservableOnSubscribe<String>() {
    @Override
    public void subscribe(ObservableEmitter<String> s)throws Exception {
    try {
     BufferedReader reader= new BufferedReader(new FileReader(filename));
     String next= reader.readLine();
     while (next != null) {
      s.onNext(next); next= reader.readLine();
     }
    } catch (IOException exn) { System.out.println(exn); } // finename err
    }
   });
```

Display is an Observer

```
readWords.subscribe(display);
```

```
final Observer<String> display= new Observer<String>() {
    ...
    public void onNext(String value) {
      System.out.println(value);
    }
    ...
  };
```

Different types of Observables (2)

Observables can be created in many different ways, e.g.

```
String[] letters= {"a", "b", "c", "d", "e", "f", "g"};
Observable<String> observable= Observable.fromArray(letters);
```

```
List<Integer> list= new ArrayList<>(Arrays.asList(1, 2, 3, 4, 5, 6));
Observable<Integer> observable= Observable.fromIterable(list);
```

```
Observable<Integer> observable= Observable.range(11, 111);
```

```
Observable<Integer> observable= Observable.just(1, 4, 9, 221);
```

https://betterprogramming.pub/rxjava-different-ways-of-creating-observables-7ec3204f1e23

RxJava Operators

```
Observable<Integer> observable= Observable.range(11, 111).take(10);
```

Use take instead of limit

```
Observable.range(11, 111)
    .filter(i -> (i%2)==0)
    .subscribe(System.out::println);
```

https://github.com/ReactiveX/RxJava/wiki/Alphabetical-List-of-Observable-Operators

Many subscribers

An observable can have several observes

important difference to Java stream !!!

```
rxPush.subscribe(display1);
rxPush.subscribe(display2);
```

Complete code in: **`code-lecture/…/TextAndButton.java`**

Combining Observables

Two observables can be combined with **`zip`**

also possible to implement for Java streams

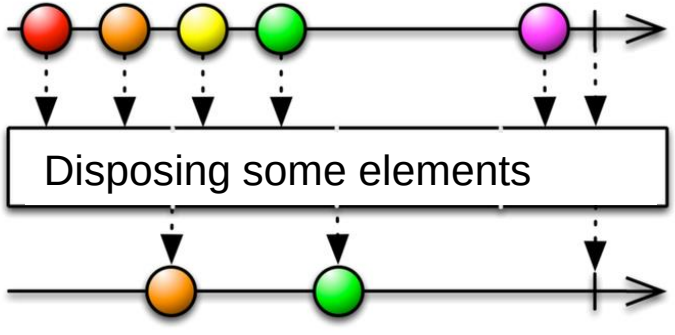
```
Observable<String> firstNames = Observable.just("James", "Jean-Luc", "Benjamin");
Observable<String> lastNames = Observable.just("Kirk", "Picard", "Sisko");

  firstNames.zipWith(lastNames, (first, last) -> first + " " + last)
        .subscribe(item -> System.out.println(item));
```

Complete code in: **`code-lecture/…/zipDemo.java`**

Source: https://github.com/ReactiveX/RxJava/wiki/Combining-Observables#zip

Backpressure

An observable may emit items so fast that the consumer can not keep up, this is called *backpressure*



Advice on handling backpressure

https://medium.com/@srinuraop/rxjava-backpressure-3376130e76c1

Schedulers

By default, an Observable emits its data on the thread where you called the subscribe method

However, you may "schedule" a subscriber on a particular thread:

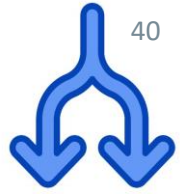
```
timer
  .subscribeOn(Schedulers.newThread())
  .filter(value -> myUI.running())
  .subscribe(display);
```

RxJava vs Java stream

RxJava	Java Stream
push-based	pull-based (terminal operator)
many subscribers	one subscriber
has rich API	few methods
must be added as dependency	built into Java

https://www.reactiveworld.net/2018/04/29/RxJava-vs-Java-Stream.html

Reactive programming



Libraries for many languages: Java, .net, JavaScript, ...

ReactiveX website

Nice introduction to RxJava: https://github.com/ReactiveX/RxJava

RxJava and the UI

(input) UI elements (buttons, textfields, ...): **observables**

(output) UI elements (textfields, ...): **observers**

Not so easy to exploit with Swing (old)

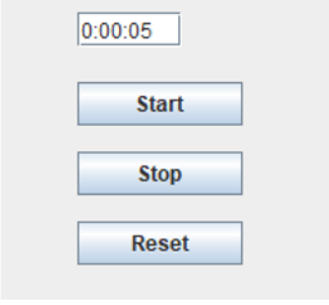
Much better in Java for Android:

```
Button button;  ...
RxView.clicks(button)
  .subscribe(aVoid -> {
        //Perform some work here//
  });
```

https://code.tutsplus.com/tutorials/rxjava-for-android-apps-introducing-rxbinding-and-rxlifecycle--cms-28565?_ga=2.125428746.1281241990.1512099718-1264555618.1502875086

RxJava version of Stopwatch

Slide 8



All three buttons must respond to clicking
When started the display must update every second

⇒ 4 streams
- one for each button
- one for handling the clock ticking

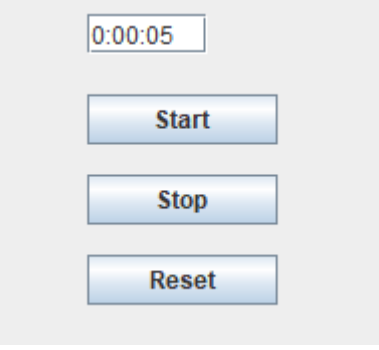
```
timer.subscribe(display);
rxPushStart.subscribe(displaysetRunningTrue);
rxPushStop.subscribe(displaysetRunningFalse);
rxPushStart.subscribe(displaysetAllzero);
```

RxJS (Javascript)

```
const button= document.querySelector("button");
   const observer = {
     next: function(value) {
       ... // handle click
     },
     error: function(err) {   ...   },
     complete: function() {   ...   }
   };

   // Create an Observable from event
   const observable= Rx.Observable.fromEvent(button, "click");
   // Subscribe to begin listening for async result
   observable.subscribe(observer);
```

https://rxjs.dev/guide/overview

Conclusion




```
timer.subscribe(display);
rxPushStart.subscribe(displaysetRunningTrue);
rxPushStop.subscribe(displaysetRunningFalse);
rxPushStart.subscribe(displaysetAllzero);
```

Agenda

- Motivation (Inherent concurrency)
- User interfaces in Java (Android, Swing, ...)
- Reactive programming (RxJava)
- **Follow up on Assignment3**

Shutting down an executor pool (week06)

```
public static void qsort(.., CyclicBarrier done, AtomicInteger count) {
if (a < b) {
  ...

  if ((j-a)>= threshold) count.incrementAndGet();
  if ((b-i)>= threshold) count.incrementAndGet();


  if ((j-a)>= threshold) {
    pool.execute(new QuicksortTask(new Problem(arr, a, j), pool, c) );
  } else qsort(...) // sequentially
  if ((b-i)>= threshold) {
    pool.execute(new solveProblem(new Problem(arr, i, b), pool, c) );
  } else qsort(...) // sequentially

  ...

  if (count.decrementAndGet() == 0) { done.await(); pool.shutdown(); }
}
```

From a solution to assignment 3

```
ExecutorService pool =
    Executors.newFixedThreadPool(noOfThreads);
for( int i = 0; i < N; i++){
  accounts[i] = new Account(i);
}

for( int i = 0; i<noOfThreads; i++) {
  try {
    pool.execute(() -> doNTransactions(NO_TRANSACTION));
  } catch(Error ex){... }
}
pool.shutdown();
```

This calls for an explanation !!!

How does shutdown work?

ExecutorService (Java Platform SE 8) - Oracle

An Executor that provides methods to manage termination and methods that can produce a Future for tracking progress of one or more asynchronous tasks.. An ExecutorService can be shut down, which will cause it to reject new tasks. Two different methods are provided for shutting down an ExecutorService.The shutdown() method will allow previously submitted tasks to execute before terminating ...

docs.oracle.com

https://docs.oracle.com/javase/8/docs/api/java/util/concurrent/ExecutorService.html#shutdown--

For the exam: you need to give an explanation either in your own words or by referring to the documentation, textbook or slides